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# Entomology and Its Future[1,2]

P. J. CHAPMAN, *New York State Agricultural Experiment Station, Cornell University, Geneva, N. Y.*

In common with other sciences, entomology has these objectives: to advance knowledge and to apply this knowledge in the promotion of man's welfare.

While our science is not dependent for a future on practical considerations, the volume and nature of activities in the field will be determined principally by future human needs for entomological information and services. What then will these needs be?

As a starting point, suppose we look at the future of some controlling human activities. Population trends is certainly one such factor.

We are in the midst of a great population upsurge (Woytinsky & Woytinsky 1953, Brown 1954). By the year 2000 or before the world's people may be twice their present number of 2.4 billion. The current rate of increase in the United States alone is more than 2.5 million annually. Can enough food be produced to feed these additional people? Primarily that question involves land and the ability to make it produce food. Only about 8 per cent of the land surface of the world is now under some degree of cultivation. More land can be made available but not much more. Most of the best land is already under cultivation.

One difficulty is that the arable land is not evenly distributed among the world's people. Thus in the United States the per capita figure is 3 plus acres but only 0.2 acre in Japan. In this country we will continue to depend primarily on the lands now being tilled to feed our growing population. This means a more intensive agriculture. And part of any such trend is more attention to pest control. For there seems to be a direct correlation between the intensification of agricultural practice and the seriousness and complexity of insect problems on the crops involved.

Science and technology have provided the American farmer with many potent tools of production. Pesticides are not the least of these tools. Given sufficient incentive, as for example a favorable price, and our farmers may quickly increase production, even exceed demand. More than anything else this means that our production potential is yet to be attained. No unsurmountable problems seem to stand in the way of feeding American populations for the next 100 years.

The situation is not so favorable elsewhere. Four-fifths of the world's people are presently undernourished, half badly so. Peoples in these "have not" countries are afflicted with a complex of interrelated problems including: overpopulation, malnutrition, a shortage of arable land, a primitive and inefficient agriculture, arthropod transmitted diseases, illiteracy, complications arising from cultural, religious and political practices and the absence of an adequate industrial development. These situations have no easy solutions. However, it is part of the continuing foreign policy of this country to help these peoples, principally by helping them help themselves.

Some of the most effective and appreciated foreign aid our nation has supplied to date is of an entomological nature. I refer in particular to the mosquito control programs for the suppression of malaria and to the control of migratory locusts. Our Foreign Operations Administration (FOA) and the World Health Organization (WHO) of the United Nations are actively aiding many countries in their arthropod-transmitted disease control programs (Price 1954). The magnitude of these operations is indicated by the FOA-supported malaria control project in India. Last year alone the homes of some 70 million Indians were sprayed with DDT.

With this brief excursion into humanistic considerations, suppose we now consider the future of our science and profession, *per se*. One of the most important events in American entomology was the union in 1953 of the American Association of Economic Entomologists and the original Entomological Society of America into a single society. This action suggests a general awareness among entomologists of the inter-dependence of all phases of our science and profession.

PROFESSIONAL TRAINING.—In a very real sense, the future of our science will be determined by the quality and training of the young people who will come into the field. Probably no two of us will wholly agree on the kind of academic training these persons should receive. However, I believe the future entomologist should first acquire a substantial grounding in the liberal arts, and basic science training in chemistry, physics, mathematics and general biology. Above all, he should become master of the written word. Far too many young people are allowed to graduate from our colleges—yes, even with the doctorate degree—without having obtained adequate skill in the use of the English language.

The ultimate goal in the student's training program of course is to qualify him as an entomologist. This properly

[1] Invitation paper, presented at the Second Annual Meeting of the Entomological Society of America in connection with the Society's observance of the Centennial of Professional Entomology.

[2] Journal paper No. 989, New York State Agricultural Experiment Station, Geneva. January 24, 1955. Accepted for publication March 17, 1955.

will require the acquisition of knowledge of all that is basic in our science—taxonomy, morphology, ecology, physiology and the rest. While this objective may be self evident, it is set forth here because some trainees are tempted to master two major fields as, for example, entomology and chemistry. The danger in such a plan is that except for the uncommon individual, the student may end up being only half trained in each field.

One compelling argument for a person to obtain the greatest possible competence in one field is that many modern research problems are best conducted through the team approach. In this age of specialization the jack-of-all trades in science is apt to become outmoded. In a team, for example, composed of an entomologist, chemist, and geneticist, the last two have a right to expect of the entomologist that he be able to handle all insect phases of the problem, and competently. The entomologist will make a better team member if he has some background in the other specializations. But first he should be as sure as may be, that he is "master in his own house."

TAXONOMY, PHYSIOLOGY.—As long as entomology exists as a science, certain workers in the field doubtless will be concerned with the identification and classification of species. Many of us know how fascinating such studies can be. Unfortunately, the number of persons who will devote a major portion of their time to such efforts is not likely to increase. However, identification will remain the key that opens the door to the accumulated knowledge on any species. Concepts in genetics, ecology and physiology are expected to exert an increasing influence on the taxonomy of tomorrow (Mayr *et al.* 1953).

Perhaps the greatest need for basic information in entomology lies in the field of physiology. This lack has long been recognized. It has only been since the introduction of the synthetic organic pesticides, however, that the need for greater knowledge in this field has become almost urgent. Reference is made in particular to the problems presented by pesticide resistant strains of arthropods and to the desirability of developing potent chemical insect killers that are relatively safe to vertebrates. Physiology has much to contribute to the solution of problems such as these and to others in the field of insect control. It is fortunate that the foregoing need has arisen at a time when revolutionary new research tools are available such as the radioactive isotopes and instruments like the electron and infra-red[3] microscopes.

MEDICAL ENTOMOLOGY.—All entomologists can take pride in the achievements of our medical entomologists during and following World War II. Thanks to DDT and the other new synthetics, great advances have been made in the suppression of arthropod transmitted diseases in many parts of the world (Rice 1954). Ultimately the world incidence of arthropod transmitted diseases may be expected to at least reach the low levels that presently prevail in the United States.

Prior to World War II scant attention was given by our Military to the control of their insect problems (Reed *et al.* 1947). DDT and what it did to eliminate the typhus outbreak in Naples in 1943–4 changed all that (Rice 1954). And at the close of World War II, there were 235 commissioned entomologists in the Army and 95 in the Navy. Now in peacetime there are about 170 professional military and civilian entomologists attached to the Services[4] distributed as follows: 135 in the Army, 15 in the Air Force and 20 in the Navy. Entomologists in any future war will first be used to keep soldiers healthy; but they will also be used to protect their food, supplies and installations from insect damage.

A number of possibilities come to mind in considering the use of insects in biological warfare. The Communists have already accused us of carrying out all kinds of activities along these lines. Sheer propaganda? Yes, but at least this much is evident from the charges: scientists behind the Iron Curtain are as aware as we are of the possibilities in this field. The use of crop pests in biological warfare would seem to have limited value unless the country against which the effort were directed was ill equipped to cope with insect outbreaks of any kind.

FOREST, REGULATORY ENTOMOLOGY.—Our forests will require an increasing amount of entomological attention. We have seen recently how effectively and cheaply forestlands can be treated from the air with DDT and other materials. In contrast to agricultural crops, however, more reliance in pest control in our forests may be placed in biological than in chemical control agents. Sound silvicultural practices and intelligent logging operations also will continue to be essential. I foresee chemical control commonly being used in our forest much as a community uses its fire department. Both are or would be used to cope with "outbreaks." Scouting and survey operations will become a vital part of forest insect control. They will permit the detection of incipient outbreaks and permit the application of chemicals or other mopping up actions.

Actual and potential pest species of the world seem destined to extend their distribution to areas outside their present range where favorable environments occur. Modern transportation and commerce are rapidly erasing all geographic barriers. Increasingly this will make the work of regulatory entomologists a delaying action. It is expected that work on the introduction and establishment of natural enemies of these introduced pests will be expanded, as of course it should be.

INDUSTRIAL, EXTENSION ENTOMOLOGY.—Industrial corporations have long made use of the services of chemists, engineers and other technical people but the entomologist is something of a newcomer in the field. Approximately a thousand professional entomologists are now employed in industry in this country. Their duties include assignments in research, products' development and sales.

The chemical industries are by their very nature ideally situated to develop new pesticides and to solve problems in their formulation. Most of the new materials of the future seem destined to originate here. And if what has taken place in chemistry is a criterion, we may expect some of the better research in insect physiology (as toxicology, primarily) to originate in industrial laboratories.

The public is becoming increasingly aware of the advantages of seeking professional aid to solve insect problems of the home, store, industrial plant and farm. Farmers are the oldest recipients of this kind of help through our tax supported Extension Service. Today, in addition to the Extension Service such service is being

[3] Combination of an infra-red spectrometer and a reflecting microscope.
[4] Determined through correspondence.

performed by representatives of the chemical industries offering pesticides and the Pest Control Operators.

An important part of the collective efforts of these people is educational. This of course is the primary function of the Extension Service. Special mention should be made here of the fine work that is being done through the 4-H Clubs to acquaint young rural people with insects.

If, as is expected, our agriculture is destined to become increasingly intensive in character, we can expect a corresponding increase in demand for pest control guidance. I believe entomologists will be called upon to give more and better service in the anticipation of pest outbreaks. This may lead to the establishment of much more elaborate machinery than we now have for survey and scouting operations. "Entomological forecasting" may become as frequent and valuable a service to the grower in planning his farm activities as is the present weather forecast.

CHEMICAL CONTROL.—Among control measures for pest species we shall continue to rely heavily on chemical measures. Their record of performance to date has been so good generally as to permit no other conclusion. This is not to say we should abandon other lines of attack. On the contrary, we should thoroughly investigate all possibilities. Biological control agents are ever ready to achieve control, by nature's standards anyway. And there are possibilities in fields like the use of radiant energy, the breeding of pest resistant varieties (including disease resistant varieties, where insects are the vectors) and the use of sanitation and other preventive practices. The use of chemicals in pest control is not an unmixed blessing. Drawbacks to their use fall into three categories: human health hazards, cost, and insect problems created by pesticide use. Suppose we examine each briefly.

Many articles have appeared over the past decade dealing with the hazards to human health in the use of pesticidal chemicals (Barnes 1953, Price 1954, Seevers 1953). These statements have ranged through the whole spectrum of position: from the factual and objective of those cited down to the rantings of the uninformed. This is our American way. No one seems to sustain any lasting hurts from these journalistic free-for-alls. And from them we usually evolve a sound understanding, acceptable to the great majority. In the present instance, the general public has now come to learn that our foods are safe, and that pesticides can be applied to crops without undue risks to the user. The Miller Amendment to the Food, Drug and Cosmetic Act, which became law in 1954, should have a much needed stabilizing effect on this whole matter.

Dollar outlays for pest control are reaching high levels for crops like the fruits and vegetables. Costs are relative things of course. Growers obviously would be unwilling to incur them if they did not prove profitable. By and large, expenditures for pest control do pay handsome dividends; in fact some crops cannot be brought through to maturity without such protection. Recognizing all this, I believe many of you share with me a feeling of uneasiness over the extent of chemical control operations in some fields. Consider a few examples (Chapman 1954). In my own State of New York it now costs about $100 an acre annually to control insects and diseases in apple orchards, entailing as many as 20 spray treatments! Costs of a similar magnitude have been mentioned for citrus in California. Disease and insect control on potatoes on Long Island is figured at $35 per acre annually and $68 an acre for sweet corn in southern Florida. Part of these costs can be charged off to the control of fungous diseases. But there must be less expensive ways to protect certain crops.

Problems that have been created by insecticide use include: the development of pesticide resistant strains, upsetting of ecological systems by the elimination of parasites and predaceous species or of altering the competitive situation between noxious forms, and effecting various undesirable changes in the host or in the soil. Of these, the resistance problem seems most pressing. To solve it, or probably more accurately to learn to live with it, we will have to become better scientists. That last at least we can enter on the credit side of the resistance "ledger."

Just what course development of insecticides will follow in the future is not clear. We often hear we should find less toxic materials. If by this is meant materials of low mammalian toxicity, then well and good. Too often, however, people confuse the inherent toxicity of a pesticide with its hazards in use. The toxicologist Seevers (1954) puts it: "No chemical must be poisons, and all chemicals can be poisons." In other words, dosage or dilution may be the controlling consideration. Thus there could be more danger of contaminating a food crop from the use of a persistent material of relatively low toxicity than in one of high toxicity that breaks down shortly after application.

Our present objective seems to be the development of chemicals that are: 1) highly toxic to insects and mites, 2) relatively safe to warm-blooded animals, and 3) products that persist about 2 weeks after application. It is expected that some pesticides of the more distant future will kill insects by subtler means than do those now employed. If it be permissible to borrow an example from the vertebrate field, then Warfarin now in use for rat control is the kind of product I have in mind.

Summing up on the use of chemical control agents then, we must as in all such situations weigh the good against the bad. I am sure any fair-minded person will conclude the benefits gained from pesticide use to date, greatly outweigh their disadvantages.

BIOLOGICAL CONTROL.—We often speak of using or of not using biological agents to control pest species as if the principle could be turned on or off at our will. This is yet another example of man's supreme egotism. Except for the introduction of natural enemies of foreign pests and some work of domestic colonization in special fields, man exerts relatively little positive effect on the course of biological control. We may of course curtail it drastically through the use of pesticides.

The ideal situation may be where chemical control is used to supplement biological control. The Japanese beetle is a good example. Here natural enemies often succeed in reducing the general population level of the insect to the point where most hosts escape economic damage and the problem of control with chemicals on hosts needing additional protection is greatly simplified. Unfortunately not all pests fit this pattern.

Compared with pesticides, biological agents have

proved too inefficient and unreliable generally, for growers of intensively grown crops like the fruits and vegetables to place primary reliance in them. The interest of growers of these crops lies in getting large yields of pest free produce. If he can only achieve this end through the use of chemicals, and continue to do so at a reasonable cost, then he will elect to use pesticides. I fear it will concern him not at all if in so doing natural enemies are killed off along with the noxious forms.

Much future effort will and should be directed towards finding ways to synchronize the use of pesticides and biological control agents. Some of the ways suggested include: the use of pesticides of low toxicity to important natural enemies (Pickett & Patterson 1953), the use of systemic pesticides (Ripper *et al.* 1951), the development of pesticide resistant strains of parasites and predators (Pielou & Glasser 1952), and restricting the use of chemical controls to part of the year only (Lewis 1948).

ATOMIC ENERGY.—No current discussion of the future of any field would be complete without some reference being made to the impact of the Atomic Age on it. I shall not attempt to discuss the consequences of an all-out atomic war. Barring that then, what effect will the availability of energy from the atom have on entomology? We know that in the radioactive isotopes we have been provided with an invaluable experimental tool for physiological and biological studies. And it may prove economically feasible to disinfest grain and other food products through applications of ionizing radiations from high frequency generators or fission by-products (Miller *et al.* 1954). We also are much interested in the principle suggested by the results obtained in the use of radiation-sterilized males in the control of the screwworm on the island of Curacao (Baumhover *et al.* 1955). However, our science and profession will probably be affected by the atomic age chiefly as human activity is affected. Brown (1954) among others has presented some interesting speculations in this area.

While the release of atomic energy may not greatly affect entomology too specifically for the foreseeable future, there is a lesson for entomologists and all other scientists to learn from the experiences of the physicists and others who had a hand in this development. It is that the modern scientist should be more than a technical expert. For increasingly he may be required to make moral, social, and political judgments based on his research or position. For an example in entomology we need look no further than the problems raised by the use of pesticides in relation to human health. If he will properly serve mankind then, the scientist of tomorrow will need to keep his technical and social development more nearly in balance.

I believe entomology has a great future. Embracing as it does a great variety of activities, the opportunities for a livelihood in the field range from practical pest control to research of the most advanced order. We have made much progress in the first 100 years of our existence as a profession. It will be judged only a beginning however, in the light of the progress we will have made tomorrow.

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# Effects of Insecticides on Flavor and Quality of Food Products[1]

VICTOR R. BOSWELL, *Horticultural Crops Research Branch Agr. Res. Serv., U.S.D.A.*

The expression "quality of food product" is rather broadly inclusive. It includes not only flavor, odor, texture, color, and appearance but also presence or absence of specific substances that are detectable only by analytical or assay methods. To keep within bounds it seems desirable to limit ourselves here to consideration of those properties that can be evaluated by careful inspection and so-called taste tests. We shall take for granted those improvements in quality that insecticides produce through elimination or minimizing of damage by insects, either directly or indirectly. We shall also take it for granted that harmful quantities of insecticides in or on food products must be prevented. That latter point is of the greatest importance, but it does not happen to be our subject here.

EFFECTS OF INSECTICIDES ON PLANT QUALITY.—With rare exceptions we ascribe to insecticides no beneficial effects other than those resulting from the control of insects. They are very rarely intended or expected to produce any direct improvement in any plant or plant product. In the absence of insecticides' general potentialities for good other than insect control, crop production and use would be much simpler if the direct effects of insecticides could be confined strictly to insects. Even then, however, we might still be faced with some flavor or quality problems resulting from the very success of insect control itself. Lest this statement appear too far-fetched, consider what happened in many potato-growing districts a few years ago when DDT came into extensive agricultural use.

The phenomenal control of potato insects by DDT contributed to such prolonged growth of the plants that in many instances, the crops were harvested when the tubers were still "immature." The skins were poorly developed, the tubers were injured excessively in harvesting, heavy losses followed in storage, and the market quality of the potatoes was disappointing. Growers have now learned artificial methods of killing the potato plants at the proper time in order to produce satisfactory quality of the harvested crop.

Such *indirect* adverse effects as that on potatoes are uncommon. Common enough are several *direct* adverse effects, most of which are usually detected in the earliest evaluations of a potential insecticide. Some direct adverse effects, however, are relatively obscure, are highly variable in their occurrence, or are delayed in their appearance. We are concerned here with such effects that either strictly limit the usefulness of an insecticide or that necessitate great care and restraint in its use.

It has often been said that if growers would adhere strictly to recommendations they would not cause trouble with certain insecticides that are suspected of impairing quality. That may be true enough, but we know that recommendations are not always followed, Furthermore, it normally takes a few years to discover the full potentialities and limitations of any new practice.

For convenience we might distinguish two main classes of direct effects of insecticides upon quality of products: (1) Effects of current treatment of the crop harvested, and (2) delayed or accumulative effects of accumulated residues of insecticides from treatments of preceding crops. It is surprisingly difficult and expensive to obtain dependable measures of possible effects of insecticides on flavor and quality. Delayed effects present the greater difficulties because the factor of time and many additional unknown or uncontrolled variables become involved.

WHY ANSWERS COME SLOWLY.—At your annual meeting in 1952, Compton (1953) pointed out some of the main difficulties in determining the effects of insecticides on flavor and quality. First, we have no adequate standards of "normal" flavor of each of the products with which we deal; and we have no adequate way to distinguish many quality factors that are merely different from those that are inferior to the standard. Second, our present methods of testing are far too slow and costly. The third and perhaps most baffling difficulty is the lack of dependable means of ruling out differences that are caused by some factor other than the insecticide under test. All of us who have taken part in this kind of work realize how baffling it can be, how cumbersome our methods are, and how inadequate our results too often happen to be.

SOME IMMEDIATE EFFECTS ON FRUITS.—Long ago it was found that arsenicals applied to citrus trees reduce the acid content of the fruit. Used with discretion they produce some desirable reduction of acid in grapefruit. In oranges, however, arsenical applications to trees tend to lower both sugar and acid of the fruit, with a consequent flat and undesirable flavor. Use of arsenicals on oranges is prohibited in Florida for this reason.

Garman *et al.* (1953) recently reported that spraying apple trees with arsenicals slightly depressed sugar content, acidity, and overall quality of fruit of the Baldwin variety; McIntosh was less affected. Applesauce from fruit of trees sprayed with DDD and chlordane was rated superior to that of trees sprayed with arsenicals. Parathion also showed a possible superiority over arsenicals in this respect. Some adverse effects of sulphur and some other fungicides were noted.

Oil-emulsion sprays long have been used on citrus trees to control certain scale and other insects. Unfortunately, these oils interfere with normal functions of the trees and thereby lower the total solids and total acids of the fruit to an undesirable level, especially when the sprays are applied late and in certain locations. The oils also delay the de-greening of the fruit and the increase of interior color. It has been recently found by Harding (1953), and by others, in Florida that parathion can be substituted for the oil sprays without lowering the quality of the fruit of Hamlin and Parson Brown oranges.

Over a dozen research papers in the past 8 years report adverse effects of BHC sprays on the flavor and odor of peaches. Light and early applications of lindane may not

[1] Invitation paper presented at the Second Annual Meeting of the Entomological Society of America held at Houston, Texas, Dec. 6–9, 1954. Accepted for publication February 14, 1955.

affect flavor of the fresh fruit, but heavier, repeated, or late applications generally do. Even the light and early applications that are not detected in the fresh fruit will probably impair the quality of the canned product. All isomers of BHC apparently contribute to poor flavor, the delta isomer having perhaps the strongest influence and alpha the least. The impairment of quality appears roughly proportional to the total isomers applied. Dosages of gamma isomer high enough to control insects will impair flavor of canned and stored peaches. The technical grade of BHC impairs flavor of both raw and canned fruit. Effects on frozen peaches are nearly as marked as upon canned ones.

In Florida, Griffiths *et al.* (1950) showed that technical BHC applications to orange trees very definitely impair the flavor of the fruit juice both fresh and canned. As in canned peaches, the off-flavor was much more marked in the canned product than in the raw or the fresh. Lindane, chlordane and toxaphene at conventional rates had no significant effect on quality but juice from such treated lots scored very slightly below the controls.

Hard & Ross' (1954) work on various malathion preparations at approximately recommended rates included apples, cherries, peaches, pears, and strawberries. The effects on flavor and quality were variable, in no case very marked, and in no case was there a definite off-flavor characteristic of the insecticide. Flavor differences in applesauce and in pears were associated with differences in acidity of the product, possibly because of differences in maturity of the samples tested. One or more times the several wettable powders and liquid concentrates, as used, each were associated with quality differences on one fruit or another, but no clear pattern of effects was evident. Hard & Ross believed that non-professional tasters would be unable to detect differences in quality that occurred in their work.

Parathion, in most studies noted, has been without effect on flavor or quality but Cochran & Van Blaricom (1950) found up to 0.3 p.p.m. in fresh and frozen peaches. None was found in the canned peaches when the last application was made 8 weeks before harvest, and none in the flesh alone 25 days after spraying. In South Africa (Coetzee *et al.* 1953) parathion appeared to impair flavor of canned tomato juice in some instances.

Chlordane was without significant effect on flavor or quality of peaches in two studies reported but in one of them (Cochran & Van Blaricom 1950) 7.5 p.p.m. was found on fresh fruit, 0.9 p.p.m. in canned and 2.9 p.p.m. in frozen peaches. Even in the absence of significant effect (Smith *et al.* 1949) noted that quality of fruit from parathion-treated and chlordane-treated trees was rather variable; some fruits were better than the controls, and others not as good.

SOME IMMEDIATE EFFECTS ON VEGETABLES.—The harmful effects of BHC in various forms on quality of potatoes is too well known to need more than mere mention here. Application of BHC or lindane to soils immediately before planting any root or tuber crop, in any amount effective against insects, is attended by great hazard if not certainty that the flavor of the harvested product will be impaired. The below-ground parts of plants have a remarkable affinity for the characteristic musty odor.

Treating the aerial parts of vegetables with BHC or lindane also is hazardous from the standpoint of product quality. True enough, not all trials of such treatments have given undesirable results. Such trials, however, have resulted in impaired quality frequently enough and on a sufficient number of different crops to indicate that BHC has little if any place in food crop production. The U. S. Department of Agriculture does not recommend technical BHC for insect control on any food crop. Lindane is recommended as a seed treatment to prevent seed-corn maggot injury to seed beans in the soil. Lindane also is recommended as a foliage spray for control of pickelworm on cucumbers although the possibility of slight off-flavor of cucumbers is recognized.

Maclinn *et al.* (1950) in 1948 and 1949 found that soil treatments with conventional doses of chlordane, lindane, or two grades of technical BHC all produced potatoes of bad to very bad flavor the year of treatment. The year following treatment the potatoes from the chlordane-treated plot were fair, from lindane fair to good, and from BHC bad. Parathion in the soil did not produce bad potatoes the year of treatment but the potatoes were, surprisingly, only fair to bad the following year. Those workers also noted that sprays and dusts of impregnated DDT and tribasic copper combined and of parathion plus copper impaired tuber quality. Even the potatoes from straight DDT-sprayed plots were off-quality in that test raising a question as to the validity of the results from some of the other sprayed plots. Pepper *et al.* (1949), at the same time found that potatoes of the immediate crop grown on soils treated with chlordane at 2 to 16 pounds and with toxaphene at 25 to 50 pounds per acre were definitely off-flavor compared with the controls. They were not so badly off, however, as those from plots with lindane and technical BHC up to 1 pound of gamma equivalent per acre.

Greenwood & Tice (1949) judged the flavor and quality of potatoes from soils treated with chlordane and with toxaphene at 1 to 8 pounds per acre and found only small differences, not correlated with treatment.

Hening *et al.* (1954) treated plots of soil at recommended and twice recommended rates with aldrin, dieldrin, and chlordane and with 50 pounds per acre of DDT and then grew several vegetable crops on the plots. Purees of carrots, peas, beans, and beets and tomato juice from the produce of the several treated plots showed no significant differences in flavor from products of the control plots. The judges tended, however, to prefer products from the controls. Squash puree was generally disliked by the judges. Squash purees from the lighter chlordane and DDT treatments were not significantly different from controls but those from aldrin treatments at 4 and 8 pounds, dieldrin at 6 and chlordane at 10 pounds per acre were rated down significantly. There was some tendency for the carrots and squash from the treated plots to be of better color than those from the control plots.

Stitt & Evanson (1949) reported that conventional dosages of parathion, chlordane, and BHC on the soil surface impaired quality of peas and beans but had doubtful effects on carrots and cucumbers. No explanation was offered for this rather unusual result with carrots in comparison with the other crops.

Campbell & Pepper (1951) observed that the solvent in

DDT emulsions may have a highly undesirable effect on flavor of potatoes. Among five solvents tested one year three were associated with potato ratings of 90 per cent, 50 per cent, and 40 per cent off-flavor, respectively.

Gilpin & Geissenhainer (1953) determined the flavor and acceptability of sweet potatoes from plots receiving repeated and excessively heavy foliage applications of toxaphene and of chlordane as 20 per cent dusts, DDT emulsion spray and 5 per cent BHC dust. Only the sweet potatoes from BHC treatments were significantly off-flavor, but those from the toxaphene treatments were only fair in overall quality. They lacked sweetness and flavor, and texture was displeasing. The product from the heavy chlordane dust treatment (26 pounds of chlordane) was rated down for astringency. A 5-pound per acre soil treatment with chlordane gave results substantially equal to the control. Despite the BHC odor in roots from BHC-dusted plants no BHC was found upon analysis. Samples from the soil-treated BHC plots showed 0.3 to 1.2 p.p.m. of BHC.

Van der Helm & Klapwijk (1950) in the Netherlands noted that technical BHC and Trilarvex, a commercial preparation of relatively pure gamma isomer of BHC, impaired flavor of carrots while their own trial with purified BHC resulted in no off-flavor. They warned, however, that under other conditions the purified form too may cause off-flavor.

Dawson *et al.* (1953) applied alpha, beta, gamma, and delta isomers of BHC to soil in pots at 12, 2, 2, and 1 pounds per acre respectively. These were the amounts that would be involved in applying 17 pounds per acre of a technical grade of BHC containing 12 per cent gamma isomer. The mixed isomers were applied at 17 pounds and also 97.7 per cent gamma isomer, and lindane at 2 pounds. All treatments except the beta and delta isomers impaired flavor of potatoes significantly. Flavor of tomatoes was not affected significantly by any single isomer but was definitely impaired by the total mixture. Lima bean flavor was impaired by the 97.7 per cent gamma isomer, by the delta isomer and by the mixture. Radishes and carrots were not impaired by 1 pound of lindane, but were by 4 pounds.

Hard & Ross (1954) found no effects of malathion on flavor or acceptability of potatoes from plots sprayed or dusted 4 times 10 to 3 weeks before harvest or of snap beans treated 3 days before harvest. Five per cent dust or 1 pint per 100 gallons of spray of a malathion emulsion (E-20-X) containing 56 per cent malathion, 35 per cent emulsifier, and 9 per cent solvent were used. Canned peas were unaffected by 1 spraying with 1 pint of E-20-X 2 weeks before harvest. Peas sprayed with 1 quart of E-20-X per 100 gallons at 19 and 9 days before harvest were very slightly different from the check, but this may have been due to maturity difference resulting from sampling difficulties. Normal use of malathion appeared without effect on quality of potatoes, beans, and peas but excessive doses should be avoided.

We can sum up the immediate direct effects of some insecticides on flavor and acceptability of vegetables as reported to date, roughly as follows:

Technical BHC in any form is likely to impart off-flavors or otherwise impair acceptability of products exposed to it; therefore it should *not* be used on food crops. Lindane is nearly as bad and is recommended only for certain seed treatments and for control of pickleworm on cucumbers for slicing.

The limited tests on malathion suggest no adverse effects from recommended usage. There is very little in the record against parathion, DDT and analogs of DDT insofar as flavor and attractiveness of product are concerned.

Effects of chlordane and toxaphene have been highly variable, offering no basis for generalizations at this time as to their probable effects on quality. They appear to produce no specific off-flavors but to have some real tendency to interfere with development of optimum quality and flavor, especially when used at relatively heavy rates.

Aldrin and dieldrin are relatively new and have, as yet, few approved applications to food crops. The few data available suggest that they are among the less harmful to flavor and attractiveness. Because of their high toxicity, however, their use must be carefully restricted. Comparative freedom from obvious effects on quality does not alone give any pesticide a favored position in the food field.

SOME IMMEDIATE EFFECTS ON PEANUTS.—Since 1950 the research branches of entomology, of human nutrition, and of horticulture in the U. S. Department of Agriculture have been involved in studies of peanut response to insecticides. The first two agencies mentioned have done the greater part of the work.

It has been shown by Gilpin *et al.* (1953) that peanuts are readily contaminated with the flavor and odor of BHC if it is applied in any form in any way to a current crop. Dosages recommended for control of soil insects were very harmful to quality regardless of whether they were applied with the fertilizer directly to the soil before planting or dusted onto the plant rows and soil surface at the time of the first cultivation. One pound of lindane per acre, for example, significantly impaired quality of roasted peanuts and of peanut butter.

The seed of the peanut has a high affinity for the flavor and odor of BHC, and some samples from treated soils have shown as high as 6.9 p.p.m. of BHC by analysis (Reynolds *et al.* 1953). A bad off-flavor, even the characteristic BHC flavor, is, however, no index of the amount of BHC that may be found on analysis. Some samples highly contaminated with BHC flavor and odor have failed to reveal any BHC upon analysis. On the other hand, considerable amounts (13 p.p.m.) of BHC dissolved in peanut oil may not be detected even by trained tasters.

The entomologists and food specialists further studied the effects of recommended and somewhat heavier dosages of aldrin, dieldrin, chlordane and heptachlor as applied to a current crop of peanuts on the flavor and quality of products (Gilpin *et al.* 1954). These four materials, applied in a number of ways, gave good insect control without impairing quality. Results with aldrin were variable; it was harmless in most cases and reduced quality in one instance.

Refined oil from peanuts from one series of treatments was used in French-frying of potatoes (Gilpin *et al.* 1953). The oil from BHC plots had a musty odor and imparted a musty odor to the fried potatoes. Oil from the aldrin plots had a slightly "strong" odor at 180° C. In general, the oils from the several treatments appeared less stable

and smoked more at 180° than oil from check lots. On second and third fryings in the oils from treated plots the potatoes tended to be progressively a little less desirable in flavor, while those fried in the check plot oils tended to be progressively a little better than the first frying. Oils from lindane and aldrin plots were roughly comparable with checks in the first runs but by the third frying they produced only fair products. Oils from technical BHC plots produced bad products at all times.

RESIDUAL EFFECTS OF INSECTICIDES ON QUALITY.—The deep-rooted tree and perennial vine crops have comparatively few of their roots in the surface few inches of the soil where residues of insecticides are localized if and when they accumulate in the soil. Although such residues may markedly affect the growth and quality of annual plants there is not yet any evidence that they produce measurable effects on quality of tree fruits.

In the production of vegetables and peanuts most of which form a large share of their roots in the plowed and cultivated zone of the soil where insecticide residues become dispersed, the situation is far different from that with trees. Furthermore the edible portion of many vegetables and of peanuts is formed below the surface of the soil so that soil contaminants may affect the sub-surface products more readily than those developing aboveground.

Several State and Federal agencies have conducted in the past 5 years a number of studies, variously joint and independent, on the tendency of certain insecticides to accumulate in soils, to persist when applied to soils, and to affect crop growth and crop quality. Because of the early indications of stability of DDT and its toxicity to some plants, and the high toxicity of BHC to many plants major emphasis was placed on plant growth and yield. As events have developed it appears that some of us at least have devoted too little attention to crop quality.

In the spring of 1950 a basic set of 11 soil treatments involving single applications of different levels and degrees of purity of DDT and BHC, and levels of chlordane was established in replicated randomized blocks by State workers in Washington, New Jersey, Georgia and Illinois, cooperating with the U. S. Department of Agriculture (Boswell *et al.* 1955). The primary object was to determine the persistence of any effects of these insecticides upon yield of several kinds of crops to be grown over a period of years, with such data on quality as were obtainable.

In Georgia, all peanuts from treated plots a year after soil treatment were rated below those from the check plots in flavor, but only heavy doses of BHC and lindane produced highly significant differences below the controls. Lindane at ½ pound; technical BHC at 24 pounds (containing 3 pounds of gamma isomer); chlordane at 8, 15, and 75 pounds; and toxaphene at 120 pounds all produced peanut butter ratings not significantly below the checks.

In the year of treatment at Prosser, Washington, rough ratings indicated that all BHC treatments (except lindane at 0.5 pound) impaired the flavor of snap beans, field beans, sweet corn and potatoes. There was no consistent or notable effect of DDT or chlordane even at very heavy doses, upon quality of beans, sweet corn, or potatoes. Aldrin at 60 pounds gave poor flavor to sweet corn and potatoes but 3 pounds was without effect.

The effects of these treatments at New Brunswick, N. J., were often much less marked than at Prosser, Wash., but as so often occurs in work of this kind there were many unexplainable and conflicting variations. Some crops were affected more the second year than the first, and sometimes heavy doses were followed by higher scores than were lighter doses. Despite these confusing observations the average quality scores over the 4-year period involving some 7,000 ratings on coded samples from 30 harvests and 8 vegetables show some differences of possible importance.

In percentage of judgments in which the New Jersey samples were rated as satisfactory, the check plots products showed 92 per cent. The 10- and 25-pound doses of DDT produced 82 per cent, and 120-pound dose 75 per cent. There was only about 2 per cent range from the 3 levels of chlordane at 8, 15, and 75 pounds, with an average of 74 per cent. Lindane at ½ pound per acre showed 73 per cent and 15 pounds showed 65 per cent. The larger amounts of technical BHC showed 62 per cent of the judgments satisfactory.

In 3 years of the New Jersey work, judgments were made on distinctiveness of flavor as well as on conformity to a reasonably high standard of excellence. In the flavor ratings on 23 crops there were 253 opportunities for differences to occur in comparison with the checks. Among these 170 significant flavor differences were noted. Not all these flavor differences were adverse. Some samples that scored 100 per cent for acceptability were rated as different from the check. Species and varieties showed differences in quality response to soil treatment. Many samples with acceptability scores well below 100 showed no flavor that was distinctly different from that of the check samples. Furthermore, the check samples often rated well below 100, and sometimes were exceeded by scores of samples from treated soil. Obviously, such data are inadequate for predicting with any degree of dependability threshold amounts of insecticide residues in soil for adverse effects.

Even if we make allowance for fairly large experimental error these extensive scores from New Jersey are highly provocative. We had not expected such lowering of average scores from the plots we call treated controls—10 pounds of purified DDT, ½ pound of lindane, and 8 pounds of chlordane, respectively.

At Beltsville, Md., we have many insecticide accumulation plots in which exaggerated dosages have been sprayed on foliage frequently to build up residues rapidly in the soil. Unsprayed crops are then grown, yields are recorded and the produce of some crops is submitted to taste panels for evaluation. Although heavy accumulations are involved single crops have shown significant differences only for BHC and lindane. Scores for various treatments have been slightly below those of the checks from time to time suggesting some adverse effect on flavor and attractiveness of snap beans and carrots, particularly Stringless Black Valentine beans from DDT and TDE plots. Aldrin, dieldrin, endrin, isodrin, chlordane, methoxychlor, toxaphene and Dilan residues had no significant effect on flavor of one crop each of beans and carrots. It remains to be seen whether averages of very large num-

bers of scores from treated plots will reveal significant effects for any insecticides in addition to BHC and lindane.

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# Field Tests with New Tick Repellents in 1954[1]

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Field tests with 21 individual repellents and 9 mixtures were conducted near Richmond Hill, Ga., during the spring of 1954, in areas heavily infested with nymphs and adults of the lone star tick, *Amblyomma americanum* (L.). The repellents were selected on the basis of their performance in laboratory screening tests against ticks, or because they were of special interest as mosquito repellents. The laboratory and field studies that preceded this work have been reported by Smith *et al.* (1946, 1948, 1950, 1954) and Cole *et al.* (1950). The repellents were cleared for limited experimental use as clothing impregnants by the Army Environmental Health Laboratory, Detachment No. 1, at Orlando, Fla., but many of them have not been completely evaluated toxicologically.

METHODS.—Regulation two-piece army fatigue uniforms of herringbone twill were impregnated at the rate of 2 grams per square foot of the individual repellents and 3.6 grams of the mixtures. The individual repellents were applied in acetone solutions and the mixtures in water emulsions. About 1,500 ml. was used to saturate a single uniform, consisting of fatigue jacket, trousers, and socks. Treated uniforms were aged on hangers in a ventilated shed and tested about once each week for 1 to 6 weeks, according to their effectiveness or interest for other reasons. Three uniforms were treated with 22 repellents and, because of insufficient materials, two uniforms with 6 repellents and one uniform with 2 repellents.

Subjects wearing the treated uniforms were exposed in tick-infested areas for 1 to 2 hours, depending on the abundance of the ticks. During the exposure time the sub-

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**Table 1.—Effectiveness of individual repellents and mixtures as clothing impregnations against the lone star tick.[a]**

| Code No. | Repellent | Per Cent Repellency | | | |
|---|---|---|---|---|---|
| | | 1–3 Weeks | | 4–5 Weeks | |
| | | Range | Average | Range | Average |
| | *Individual Repellents* | | | | |
| 5974[b] | Quinoline, 1-butyryl-1,2,3,4-tetrahydro- | 88–94 | 91 | 93–95 | 94 |
| 12216 | 3,5-Decanediol, 2-methyl- | 90–97 | 93 | 71–87 | 79 |
| 8118 | Octanoic acid, tetrahydrofurfuryl ester | 92–96 | 94 | 82–85 | 83 |
| 22542-b[b] | *m*-Toluamide, *N,N*-diethyl- (crude) | 85–95 | 90 | 77–84 | 80 |
| 20297 | Benzamide, *o*-ethoxy-*N,N*-diethyl- | 87–94 | 91 | 66–83 | 74 |
| 20127 | Mandelic acid, amyl ester | 90–94 | 93 | 68–69 | 68 |
| 6584 | 2-Cyclohexene-1-carboxylic acid, 6-ethyl-2-methyl-4-oxo-, ethyl ester | 82–94 | 89 | 83 | 83 |
| 7627 | Carbostyril, 1-butyl-4-methyl- | 86–93 | 89 | 81 | 81 |
| 6397[b] | Glutaramic acid, *N,N*-diisopyl-, propyl ester | 85–93 | 89 | 79 | 79 |
| 6252 | Succinamic acid, *N,N*-dipropyl-, ethyl ester | 87–91 | 89 | 75 | 75 |
| 12191 | 1,3-Heptanediol, 2-propyl- | 84–89 | 87 | 75 | 75 |
| 6275 | Succinamic acid, *N,N*-diethyl-, isobutyl ester | 76–85 | 82 | — | — |
| 5950 | Cyclohexanol, 2-phenethoxy- | 73–82 | 78 | — | — |
| 6498[c] | Cyclohexanecarboxylic acid, 1-hydroxy-2-butoxyethyl ester | 27–95 | 69 | — | — |
| 11190 | Hydrocinnamic acid, *beta*-hydroxy-*alpha*-methyl-, ethyl ester | 79–83 | 81 | — | — |
| 5756 | Benzyl alcohol, *o*-butoxy- | 69–91 | 80 | — | — |
| 14643 | Benzamide, *p*-chloro-*N,N*-diethyl- | 74–87 | 80 | — | — |
| 5023[b] | 2-Cyclohexene-$\Delta^1$, *alpha*-acetic acid, *alpha*, 3,5,5-tetramethyl-, methyl ester | 81 | 81 | — | — |
| 13211 | Octanoic acid, 4-ethyl-3-hydroxy-, allyl ester | 79 | 79 | — | — |
| 6496 | Cyclopentanecarboxylic acid, 1-hydroxy-, tetrahydrofurfuryl ester, acetate | 57 | 57 | — | — |
| 6619[d] | Succinamic acid, *N,N*-dipropyl-, allyl ester | 78 | 78 | — | — |
| | *Mixtures*[e] | | | | |
| M-1960 | 375 (30%), 2484 (30%), 523 (30%) | 93–100 | 95 | 95–96 | 95 |
| M-2084E | 20297 (45%), 22542 (45%) | 79–99 | 89 | 68 | 68 |
| M-2076 | 523 (30%), 3775 (30%), 20127 (30%) | 83–89 | 86 | 72 | 72 |
| M-2077 | 523 (30%), 3775 (30%), 20297 (30%) | 76–96 | 85 | 63 | 63 |
| M-2075 | 523 (30%), 3775 (30%), 7627 (30%) | 71–85 | 80 | 86–86 | 86 |
| M-2072E | 262 (36%), 375 (27%), 20297 (27%) | 74–85 | 80 | 44 | 44 |
| M-2085E[b] | 22542 (30%), 375 (30%), 20297 (30%) | 72–83 | 78 | 84 | 84 |
| M-2087[c] | 22542 (30%), 523 (30%), 20297 (30%) | 70–80 | 75 | — | — |
| M-2086[b] | 283 (45%), 523 (45%) | 24–81 | 52 | — | — |

[a] Average of three uniforms except as indicated.
[b] Two uniforms.
[c] One uniform.
[d] Irritating to the skin.
[e] All mixtures contained 10% of Tween 80 as emulsifier. The individual repellents are:

262—Dimethyl phthalate
375—2-Ethyl-1,3-hexanediol
283—Dibutyl phthalate
523—Benzyl benzoate
2484—*N*-Butylacetanilide
3775—2-Butyl-2-ethyl-1,3-propanediol
7627—1-Butyl-4-methyl carbostyril
20127—Amyl mandelate
20297—*o*-Ethoxy-*N,N*-diethylbenzamide
22542—*N,N*-Diethyl-*m*-toluamide (crude)

jects alternately walked about, sat, and lay on the ground, all doing the same thing to give equal exposure. After the exposure they remained in an uninfested location for about 1 hour to give the ticks time to attach, or to drop off or die, according to the effectiveness of the repellent. In each test one subject wore an untreated uniform as a check. At the end of the waiting period the uniforms were removed and all ticks on the clothing and body were counted. The effectiveness of the repellent was determined on the basis of the total number of attached and unattached ticks, as previous studies had shown this to be the most suitable basis of evaluation.

RESULTS.—The results for the first 5 weeks are summarized in table 1. None of the new mixtures were as effective as the standard M-1960, which gave an average repellency of 95 per cent for the first 5 weeks. Three of the mixtures—M-2075, M-2076, and M-2077—were similar to M-1960 but contained 1-butyl-4-methyl-carbostyril (7627), amyl mandelate (20127), or *o*-ethoxy-*N,N*-diethylbenzamide (20297), respectively, in place of *N*-butylacetanilide (2484), and of these the most effective after 4 to 5 weeks was M-2075. Three of the mixtures were developed for use as skin applications against mosquitoes, M-2084E, M-2072E, and M-2085E, and of these the most effective after 4 to 5 weeks was M-2085E. The dibutyl phthalate-benzyl benzoate mixture, developed previously for use against chiggers, showed an average repellency for 2 weeks of only 52 per cent.

The most effective individual repellent was 1-butyryl-1,2,3,4-tetrahydroquinoline (5974), which gave an average repellency of 91 per cent for the first 3 weeks, 94 per cent after 4–5 weeks, and 100 per cent after 6 weeks. Five other compounds that showed average repellencies of at least 90 per cent for the first 3 weeks were tetrahydrofurfuryl ester of octanoic acid (8118), crude *N,N*-diethyl-*m*-toluamide (22542-b), 2-methyl-3,5-decanediol (12216), *o*-ethoxy-*N,N*-diethylbenzamide (20297), and amyl mandelate (20127).

SUMMARY.—Field tests with 21 individual repellents and 9 mixtures were conducted in areas heavily infested with nymphs and adults of the lone star tick, *Amblyomma americanum* (L.). None of the new mixtures was as effective as the standard, M-1960. Three of the mixtures were developed for use as skin applications, and of these the most effective after 4 to 5 weeks was M-2085E, containing crude *N,N*-diethyl-*m*-toluamide *o*-ethoxy-*N,N*-diethylbenzamide, and 2-ethyl-1,3-hexanediol in equal parts. The six most effective individual repellents were 1-butyryl-1,2,3,4-tetrahydroquinoline, tetrahydrofurfuryl ester of octanoic acid, crude *N,N*-diethyl-*m*-toluamide, 2-methyl-3,5-decanediol, *o*-ethoxy-*N,N*-diethylbenzamide, and amyl mandelate.

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# Chemical Control of the Mountain Pine Beetle and Douglas-Fir Beetle[1]

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During the period from 1951 to 1953, experiments were conducted at Windermere Creek, British Columbia, to explore the use of chemical control methods against the mountain pine beetle, *Dendroctonus monticolae* Hopk., in lodgepole pine and the Douglas-fir beetle, *Dendroctonus pseudotsugae* Hopk., in Douglas-fir. Two approaches were taken: bark-penetrating and residue sprays were applied to standing infested trees, and concentrated systemic poisons were injected into the sapstream of freshly attacked trees and healthy trees prior to felling.

Attempts to control bark beetle outbreaks in western North America have been based on several costly and sometimes hazardous methods. The oldest method was to burn standing infested trees or to fell the trees and burn the logs. The injection of chemicals such as zinc chloride and copper sulphate into infested trees has been partially successful, but the precise timing and relatively elaborate techniques required limited the usefulness of this method.

The success of bark-penetrating fumigant sprays was first demonstrated by Salman (1938). Orthodichlorobenzene, paradichlorobenzene, crude flake naphthalene, and beta-naphthol in fuel oil gave satisfactory mortality of beetles in several species of pine. Gibson (1943) experimented with several oil-fumigant formulations and concluded that orthodichlorobenzene in diesel oil combined efficacy with the least cost for control of *D. monticolae* in lodgepole pine. It was found later that this spray gave comparable results when it was sprayed on the trunks of standing trees. The shortage of orthodichlorobenzene and the high cost of woods transportation of fuel oil prompted the work of Massey *et al.* (1953a, 1953b). They concentrated on the use of oil-in-water emulsions of fumigants. Several fumigants and solvents were tested in emulsions containing various percentages of oil with the resultant recommendations of 2 pounds of ethylene dibromide in 5 gallons of fuel oil emulsion for *Dendroctonus ponderosae* Hopk. in yellow pine, and 3 pounds of ethylene dibromide in 5 gallons for *Dendroctonus engelmanni* Hopk. in Engelmann spruce.

SYSTEMIC INSECTICIDE EXPERIMENTS.—It was initially demonstrated that schradan and Systox were toxic to *D. monticolae*. Strips of lodgepole pine bark were soaked for 5 minutes in water dilutions of the concentrates. After the excess moisture had evaporated, 14 healthy adult beetles were enclosed with the bark in tight containers. Schradan diluted 1:330, 1:500 and 1:1000, and Systox diluted 1:600, 1:900 and 1:1800 with water were used. Five days after treatment, mortality results were as follows: schradan—64, 64, and 79 per cent respectively, and Systox—100, 100 and 79 per cent respectively. Beetles enclosed with only water-moistened bark suffered only 29 per cent mortality. In a similar experiment, comparable results were obtained for *Ips interpunctus* (Eich.). Later, 5 gallons of each of these diluents were poured around the roots of healthy lodgepole pine. Two weeks after treatment, the trees were felled, but subsequent *Ips* attacks showed that the treatments were ineffective.

During the three seasons, 1951 to 1953, attempts were made to inject concentrates of these insecticides into lodgepole pine freshly attacked by *D. monticolae*. Elaborate injection techniques were avoided so that if the treatments were effective, they would also be practical on a large scale. Trees were girdled by removing 2 to 4 inches of bark from the circumference at 2 feet above ground. Three methods of applying concentrated solutions to the girdles were used: (1) Schradan- and Systox-soaked cotton strips were tacked around the exposed wood and were either left exposed or were covered with paraffin-impregnated cotton strips, (2) absorbent cotton strips, soaked in slightly diluted Systox, were packed around the cut and covered with paraffin-impregnated cotton strips, (3) a paste of Systox and domestic flour was applied in the same manner as in (2).

A total of 27 trees were treated by these methods from 1 to 3 weeks after the beetles attacked in early August of 1951 and 1952. When broods were examined during each summer following the applications, no outstanding treatment effects were observed. Two experiments showed that in trees treated with Systox paste or absorbent cotton, the mortality of parent adults was higher, and the survival of the progeny lower than in control trees at 5 feet above the girdle. Samples at the 15- and 25-foot levels, however, showed no difference between treatments and checks. Beetle mortality at the 5-foot level was lower in trees treated 3 weeks after attack than in those treated within a week after attack.

A 50% concentrate of Systox was painted on the girdle of a small Douglas-fir at the beginning of June, 2 weeks after it had been attacked by the Douglas-fir beetle. Bark examinations 1 month later showed that the parent adults had abandoned their galleries and that their progeny failed to develop in the basal 10 feet of the stem. Mortality of the progeny at 15, 20 and 30 feet averaged 46 per cent. Neither abandonment nor mortality were noted in the check tree.

Concentrated schradan was also applied to frill girdles in 10 healthy Douglas-fir trees in an attempt to use poisoned trees as trap logs for the Douglas-fir beetle. The trees were treated on May 20, and felled on May 24, 1953. The beetles commenced attack on May 29, and continued to attack intermittently throughout June. All beetle attacks were tagged as they occurred. Ten-foot factory cotton trays were constructed under each log at 10 to 20 feet from the butt. The total numbers of attacks and dead beetles collected from the trays indicated that the beetles were neither repelled by the treated logs, nor poisoned sufficiently to drop on the trays in significantly greater numbers than on control trays. Brood examinations in July and August showed a slight treatment effect

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just above the girdles, but the overall reduction in survival was too slight to be of any practical value.

BARK SPRAYS.—*Methods.*—Pilot experiments were set up by treating infested blocks 2 to 3 feet long. These blocks were brought to the field camp where the ends were immediately waxed to reduce desiccation. Sprays were applied with a bucket pump and a nozzle that deliver a hollow cone spray. Formulations that showed promise in the pilot experiments were later field tested on standing trees. The trees were sprayed using a bucket pump and a 9-foot extension boom equipped with a solid stream nozzle. With this extension, it was possible to spray to a height of 33 feet from level ground. The stream was applied as high as possible up the trunk, and then played down the trunk as the liquid began to run down the bark. The entire bark surface of a tree was easily covered from spray settings on three sides.

Materials and sampling methods varied; those that are pertinent are described in the following section. Residual insecticides were tested in addition to the volatile bark-penetrating chemicals that have given good results in previous work. In deference to the cost considerations outlined by Massey *et al.* (1953a) most of the insecticides were tested in emulsions rather than in oil solutions.

*Experiments and Results.*—Experiments conducted during 1951 have been summarized by Randall (1952). Relatively low concentrations of insecticides were used and fast-breaking emulsions were formulated with domestic detergent.

In pilot tests, DDT, ethylene dibromide and orthodichlorobenzene were formulated at the rate of 0.8 pounds of active ingredient per 5 U.S. gallons[3] of emulsion containing 20 per cent fuel oil (V/V). Lodgepole pine blocks treated with these sprays when *D. monticolae* broods were nearing maturity showed excellent control of larvae and pupae, but mortality of young adults was slight. Bark samples were examined prior to the beetle emergence period. These insecticides, plus chlordane, were also tested at the same rate against *Ips interpunctus* (Eich.) and *Pityogenes carinulatus* (Lec.) when young larvae and parent adults were present. Chlordane and DDT gave excellent control of parent adults but mortality of the progeny for all treatments was negligible.

Standing pines that were sprayed with this amount of active ingredient at the beginning of July, 1951, showed that chlordane and DDT effected 78 and 76 per cent mortality of mature larvae, pupae, and young adults respectively, whereas ethylene dibromide and orthodichlorobenzene caused only 36 and 23 per cent kills. Each treatment was repeated on five trees; mortality estimates were based on samples at 5, 15, and 25 feet above ground.

In late August, 1951, shortly after lodgepole pine trees were attacked by the beetle, ethylene dibromide, chlordane, DDT, and orthodichlorobenzene formulated at 1.3 pounds per 5 gallons with 33 per cent fuel oil were sprayed on standing trees to a height of 10 feet. Each treatment was repeated on six trees. Samples were cut at 2 and 7 feet above ground during the following July. In comparison with the check trees, the percentage reductions in brood survival were as follows: ethylene dibromide—100 per cent; chlordane—86 per cent; DDT—63 per cent; and orthodichlorobenzene—37 per cent.

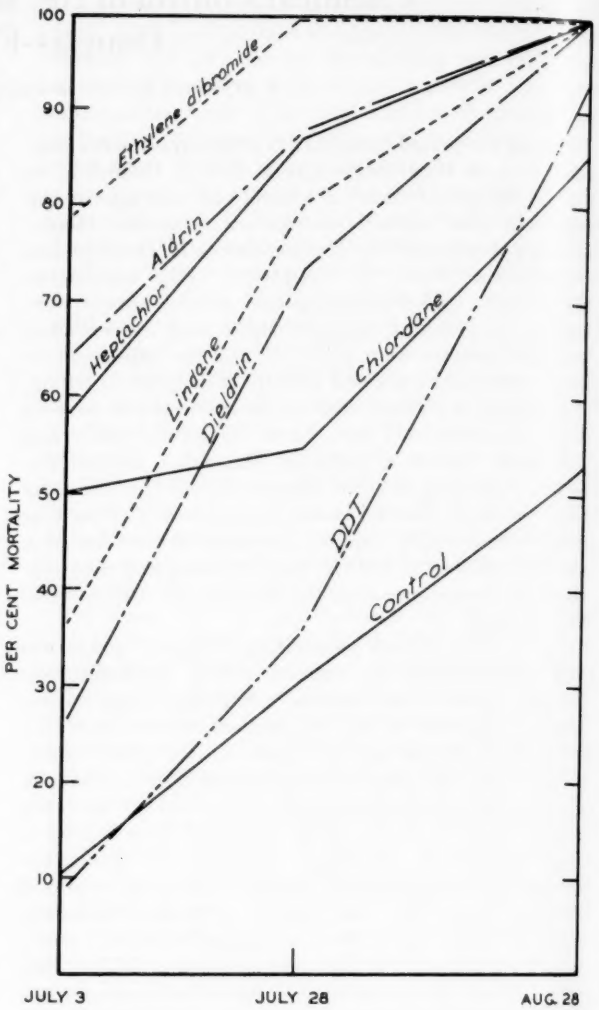


FIG. 1.—Effectiveness of seven insecticides against the mountain pine beetle in pilot test sections of lodgepole pine (3 replications).

During 1952, testing was limited to pilot experiments. On June 18, 9 insecticides were sprayed on pine blocks infested with large larvae of *D. monticolae.* Technical grades of ethylene dibromide, orthodichlorobenzene, DDT, toxaphene, and lindane, and emulsifiable concentrates of aldrin, dieldrin, heptachlor, and chlordane were used. Solvents were fuel oil for ethylene dibromide and orthodichlorobenzene, acetone for toxaphene and lindane, and Velsicol AR50-G for DDT. All insecticides were formulated at the rate of 3.2 pounds per 5 gallons with the exception of lindane, which was used at the rate of 0.64 pounds. Each formulation contained 20 per cent fuel oil which was emulsified with 6 ounces of a blend of 3 parts of Triton X-100 and 5 parts of Triton B-1956. One-half-square-foot bark samples were examined on July 3 and 28, and 1-square-foot samples were examined on August 28 after all of the surviving progeny had emerged. The results, which are illustrated in figure 1,

[3] In order to facilitate comparisons with previous work, all formulations have been converted from Imperial to United States fluid measure.

show that ethylene dibromide effected rapid and thorough mortality and that several of the residual insecticides eventually were of comparable value. Orthodichlorobenzene and toxaphene results have been omitted because of the variable and low mortality estimates given by the small samples. It is interesting to note that the more volatile insecticides effected higher mortality at the earlier examination dates than the less volatile chemicals.

Four of the foregoing treatments were sprayed on two Douglas-fir logs which were divided into treatment zones 5 feet long. Sprays were applied in September when *D. pseudotsugae* broods were in the pupal and teneral adult stages. Bands of bark 1 foot in width around the log were examined on each zone during the following July after the surviving progeny had emerged. Although survival in the control zones was poor, the following averages of emergence holes per square foot indicates the treatment effects: ethylene dibromide 0.1, heptachlor 0.2, aldrin 0.4, lindane 1.0, and control 3.7. The average bark thickness was 0.74 inch.

Another pilot experiment was designed to test ethylene dibromide against *D. monticolae*. Pine sections were sprayed on July 15 when the broods were predominantly pupae. Three concentrations of ethylene dibromide were formulated in the four percentages of fuel oil shown in table 1. The lowest level of oil at each concentration was the minimum required to dissolve each volume of technical grade insecticide. The Triton blend of emulsifiers was used to emulsify all sprays except the oil solutions. Samples were examined on the dates shown. The results indicate that as little as 3.5 per cent oil with 3.2 pounds of ethylene dibromide is as effective as sprays containing a higher proportion of oil, but that 20 per cent oil is required to achieve adequate mortality when formulated at the 1.6 pound rate.

Ethylene dibromide, lindane, and aldrin were field tested on standing infested pine during 1953. The 1952 pilot test formulations were used with the exception of the aldrin spray in which the fuel oil and emulsifiers were omitted. (The commercial emulsifiable concentrate of this insecticide contained only 20 per cent active ingredient, so that if oil were added, the amount of water would be reduced to only 40 per cent.) Each compound was sprayed on 10 trees at the beginning of June. The average diameter and bark thickness of all the experimental trees were 10.4 and 0.14 inches respectively. Since all the trees were on a steep slope, spray height was about 36 feet on the uphill sides and 30 feet on the downhill sides of the trunks. The average dosage was 4.0 U.S gallons per tree, or the equivalent of 4.4 gallons per 100 square feet of bark surface.

Table 1.—Effectiveness of ethylene dibromide against the mountain pine beetle in pilot test sections of infested lodgepole pine.[a]

| Treatment | | Per Cent Mortality | |
|---|---|---|---|
| Pounds of Ethylene Dibromide per 5 Gallons of Emulsion | Per Cent Fuel Oil (V/V) | July 28 (0.5 sq. ft. sample) | August 28 (1.0 sq. ft. sample) |
| 1.6 | 1.7 | 65 | 85 |
| | 20 | 90 | 98 |
| | 50 | 95 | 98 |
| | 100 | 99 | 98 |
| Control | — | 31 | 20 |
| 3.2 | 3.5 | 97 | 100 |
| | 20 | 100 | 99 |
| | 50 | 100 | 100 |
| | 100 | 100 | 100 |
| Control | — | 29 | 31 |
| 4.8 | 5.1 | 90 | 99 |
| | 20 | 97 | 100 |
| | 50 | 99 | 100 |
| | 100 | 100 | 100 |
| Control | — | 18 | 44 |

[a] Four replications.

Table 2.—Effectiveness of emulsion sprays against the mountain pine beetle in standing lodgepole pine.[a]

| Treatment | Height Above Ground (Feet) | | | | |
|---|---|---|---|---|---|
| | 5 | 15 | 25 | 35 | All Heights |
| (Ave. no. of emergence holes and living insects per sq. ft.) | | | | | |
| Control | 16.6 | 18.8 | 12.9 | 14.0 | 15.6 |
| Ethylene dibromide | 0.0 | 0.2 | 0.8 | 4.2 | 1.3 |
| Aldrin | 1.6 | 0.8 | 2.1 | 6.2 | 2.7 |
| Lindane | 2.2 | 0.5 | 2.4 | 3.9 | 2.3 |
| L.S.D. 1% level | 9.1 | 9.5 | 4.9 | 9.4 | — |
| (Ave. no. of dead pupae and teneral adults per sq. ft.) | | | | | |
| Control | 0.2 | 0.7 | 0.8 | 1.1 | 0.7 |
| Ethylene dibromide | 0.4 | 0.6 | 0.8 | 0.4 | 0.5 |
| Aldrin | 15.7 | 11.7 | 15.9 | 6.9 | 12.6 |
| Lindane | 7.3 | 7.0 | 7.9 | 1.3 | 5.9 |
| L.S.D. 1% level | 6.5 | 4.9 | 6.7 | 4.4 | — |

[a] Ten replications.

The trees were felled at the end of August and 1-foot bands of bark were examined at the heights shown in table 2. Dead larvae were so small that it was not possible to obtain an accurate count of this stage, but dead pupae and teneral adults were recorded. Survival was based on the numbers of emergence holes and living insects. At the time of examination, 92 per cent of the surviving progeny had emerged from the untreated trees.

A simple statistical comparison test was applied to each sample height after the data were converted to values per square foot. Table 2 shows that at all heights, the three treatments differ significantly from the controls, but that differences between sprays were not significant. The numbers of dead pupae and young adults show that aldrin remained ineffective until the beetles commenced to emerge. In this respect, lindane was intermediate between the other two treatments. Aldrin and lindane were still effective after the trees were exposed to 5.9 inches of rain which fell between the treatment and examination dates. The reduced effectiveness of all treatments at 35 feet can be attributed to the aforementioned variation in spray height.

Discussion.—Although the treatment of infested trees with concentrates of the systemic poisons failed to reduce brood survival, more elaborate techniques of injecting dilute systemics may yield some success. Nevertheless, the rapid occlusion of the xylem conductive

tissue by bluestaining fungi associated with the beetles reduces the effective treatment period so much that the practicability of the method would be in question.

The ethylene dibromide results are consistent with the findings of Massey *et al.*, and there is little doubt that it combines minimum cost with minimum concentrate bulk, and with consistent high and rapid mortality. Although aldrin, lindane, and several of the residual insecticides are costly, their high effectiveness indicates that they may be useful against bark beetles that breed in very thick-barked trees. Timing may limit their use, since the best results would probably be achieved if the period between treatment and beetle emergence is minimized.

Although it has been demonstrated that a large percentage of beetles infesting trees can be killed with heat or chemicals, the significance of the residual beetle population remains unanswered. The factors affecting population release and host resistance may be so important that an outbreak will run its course despite control operations. Timely applied control of a high proportion of infested trees of an incipient outbreak may be sufficiently effective to justify costly methods. On the other hand, the number of trees that must be treated to curb an epidemic population may be so large that applied measures would be impractical. Thorough studies of both endemic and epidemic populations are required to clarify both the feasibility and the required extent of control measures during outbreaks. Further pilot testing of the insecticides should be resumed only when additional information from population studies is available.

SUMMARY.—It was demonstrated that Systox and schradan were toxic to the mountain pine beetle. However, the application of concentrates to mountain pine beetle-infested lodgepole pine by the methods described failed to reduce brood survival.

Bark sprays of two fumigants and seven residual insecticides were pilot tested on blocks of lodgepole pine infested with *Dendroctonus monticolae*. Ethylene dibromide, aldrin, heptachlor, lindane and dieldrin, formulated at the rate of 3.2 pounds of active ingredient in 5 gallons of emulsion, gave the best control, although the ethylene dibromide effected most rapid mortality. A pilot test against the Douglas-fir beetle indicated that ethylene dibromide, aldrin, and heptachlor formulated at the foregoing rate were effective against this species in relatively thin-barked Douglas-fir. Field tests of three of these insecticides at this rate against the mountain pine beetle in standing pine showed that aldrin and lindane were equally as effective as ethylene dibromide. Pilot and field experiments showed that at a rate of 0.8 pounds per 5 gallons, chlordane and DDT effected better, although inadequate, mortality of *D. monticolae* than ethylene dibromide or orthodichlorobenzene. A pilot test of ethylene dibromide alone indicated that a formulation of about 2 pounds in 5 gallons of emulsion containing 20 per cent fuel oil provides an effective spray with a margin for inadequate bark coverage.

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# Further Observations on the Control of the Walnut Aphid[1]

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The walnut aphid, *Chromaphis juglandicola* (Kltb.), is one of the most serious insects attacking walnuts in northern California. It is ever present, and large populations can be expected each year. Natural enemies are very important in holding the pest in check. Experience has shown that unless aphicides directed against the pest result in the near eradication of the aphid from treated orchards, control should be left to natural enemies, (Michelbacher & Bacon 1952). Ineffective materials may adversely affect natural enemies and allow the aphid population to increase to a higher level than had nothing been done.

Where DDT is used to control the codling moth, it is a recommended practice to use it in combination with an effective aphicide, for DDT has been shown to stimulate an increase in the aphid population to destructive proportions (Michelbacher *et al.*, 1950). Recent investigations, however, have shown that if an effective systemic aphicide was used in combination with the spray directed against the first brood of codling moth, no aphicide need be added if a second spray is applied to control the second brood of codling moth. The reason for this is that the systemic aphicides have sufficient residual action to insure the control of the aphid following the second application of DDT.

In most orchards aphid control is desirable, providing effective programs are followed. With the non-systemic aphicides now available, satisfactory control for an entire season may be obtained with from two to three timely applications. The most critical period to hold the aphid in check is from early May until the end of August. Aphid populations before this time apparently do not adversely

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influence the quality of the nuts, and populations which develop after the end of August are not too harmful. Late season aphids excrete less honey dew than those that appear earlier in the season.

There are a number of factors other than aphids that adversely affect the quality of the nuts. Important among these are improper cultural care, attacks by other insects and spider mites, and unfavorable weather conditions. At times these factors interfere and make it very difficult to accurately appraise the role played by the aphid. Often reduced quality is attributed to the walnut aphid, where actually other factors are to blame.

In recent years, the major portion of the investigations on walnut insects has been devoted to studies concerning the walnut aphid. Effort has been directed towards trying to evaluate the true benefit of aphid control in relation to other factors affecting the quality of the harvested crop. The availability of systemic insecticides greatly facilitated this study.

The investigations have been conducted in several places in northern California, which include both interior (Linden and Modesto) and more coastal localities (Walnut Creek and San Jose). Wherever possible, treatments were replicated and, in order to reduce interference of aphicides with one another, large plots were used. Except for preliminary testing, the smallest plots were 2 acres, but by the far the greatest number were 4½ or more acres in extent.

Aphid population trends were determined by counting all the aphids that occurred on the underside of the next to the terminal leaflet of a walnut leaf. The leaflets were gathered at random about the skirt of the tree. Usually not more than five leaflets were taken from a single tree, and either 50 or 100 leaflets were examined per plot.

The principal aphicides investigated were parathion, malathion, nicotine, BHC, Systox, and schradan.[2] These materials were used either alone or in combination with sprays directed against the codling moth.

Most extensive series of experiments have been conducted at Linden, which is located in the northern portion of the San Joaquin Valley. Results of aphid control at this locality in 1953, where aphicides were incorporated with sprays directed against the codling moth on the Payne variety of walnut, are given in table 1. All the aphicides, whether applied with an air carrier or a conventional sprayer, resulted in excellent control of the aphid from early May through July 1. Parathion 25% wettable powder applied with an air carrier sprayer at 1 pound per acre resulted in slightly better control than 1½ pounds per acre applied with a conventional sprayer. This confirms results obtained in previous years, where aphicides applied with air carrier sprayers have out performed the same material applied at higher dosages with conventional sprayers. The results in table 1 also show that the systemic aphicides gave better control than the non-systemic materials; further, control with schradan exceeded that obtained with Systox.

On July 1 and 2, all plots except those receiving Systox and schradan were retreated, using a high capacity air carrier sprayer. Aphid control following the July treatment is given in table 2. Although not retreated, the population trends for Systox and schradan treatments are included in the table for comparison. Table 2 is a continuation of table 1 except for the discontinued plots sprayed with the conventional sprayer. Excellent control was obtained with all of the July applications. The population held to a rather low level until the end of August. In September, there was a rapid increase in the population, but a large developing predator population adequately checked it. This accounts for the decline noted on the survey conducted September 23. Turning to the systemic insecticides, it is evident that the Systox treatments held the aphid in check well into August, and that the degree of control fairly closely paralleled the dosage applied. The decline observed on September 23 as with the other treatments was due to an increasing predator population. The control obtained with schradan

**Table 1.—Aphicides used in conjunction with the codling moth spray against the walnut aphid on Payne variety of walnut at Linden, California. 1953.**

| Aphicide and Pounds per Acre | Average Number of Aphids per Leaflet on[a] | |
|---|---|---|
| | June 16 | July 1 |
| *Air Carrier Sprayer*[b] | | |
| 25% parathion W.P., 1 | 0.23 | 1.83 |
| 25% malathion W.P., 3 | 0.11 | 1.67 |
| 14% nicotine dry concentrate, 7 | 0.09 | 1.62 |
| Systox (actual) | | |
| 0.25 | 0.15 | 0.19 |
| 0.50 | 0.42 | 0.61 |
| 0.75 | 0.28 | 0.45 |
| 1.00 | 0.05 | 0.06 |
| 1.25 | 0.01 | 0.22 |
| Schradan (technical) 2.5 | 0.20 | 0.00 |
| *Conventional Sprayer*[c] | | |
| 25% parathion W.P., 1.5 | 0.24 | 3.36 |
| BHC, 6% gamma isomer, 9 | 0.36 | 3.50 |

[a] Prior to treatments applied May 6 to 9, the average number of aphids per leaflet on May 6 was 4.97. No aphids were found in any of the treated plots on May 9, 18, or June 1.
[b] Applied in 200 gallons of water per acre.
[c] Applied in 1000 gallons of water per acre.

[2] Product used contained 1.56 pounds octamethylpyrophosphoramide and 0.44 pound related organic phosphates per gallon.

**Table 2.—Aphicides for midseason control of the walnut aphid at Linden, California, 1953.[a]**

| Aphicide and Pounds per Acre | Average Number of Aphids per Leaflet on | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | July 1[b] | July 6 | July 20 | Aug. 3 | Aug. 19 | Aug. 31 | Sept. 14 | Sept. 25 |
| 25% parathion W.P., 1 | 1.83 | 0.00 | 0.00 | 0.02 | 0.71 | 8.99 | 29.44 | 18.53 |
| 25% malathion W.P., 3 | 1.67 | 0.00 | 0.00 | 0.00 | 0.90 | 5.93 | 36.34 | 19.05 |
| 14% nicotine dry concentrate, 7 | 1.62 | 0.00 | 0.00 | 0.02 | 0.71 | 3.15 | 17.08 | 14.34 |
| Systox (actual) | | | | | | | | |
| 0.25 | 0.19 | 0.00 | 0.04 | 0.30 | 6.40 | 15.0 | 44.0 | 8.40 |
| 0.50 | 0.61 | 0.17 | 0.37 | 0.37 | 5.96 | 22.97 | 17.61 | 4.68 |
| 0.75 | 0.45 | 0.09 | 0.14 | 0.22 | 3.59 | 19.26 | 19.08 | 5.81 |
| 1.00 | 0.06 | 0.00 | 0.01 | 0.10 | 2.93 | 10.99 | 29.31 | 9.46 |
| 1.25 | 0.22 | 0.02 | 0.11 | 0.13 | 0.91 | 8.02 | 22.90 | 7.17 |
| Schradan (technical), 2.5 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.13 | 0.03 | 0.03 |

[a] With the exception of the Systox and the schradan treatments which were applied May 6 to 8 inclusive in the codling moth spray, all other treatments were reapplied July 1 and 2 with an air carrier sprayer in approximately 50 gallons of water per acre.
[b] Pre-treatment count.

was outstanding. Even at the end of the season, the trees were nearly free of aphids.

At harvest, a test was made by cracking field run nuts from which obvious culls had been removed to determine the quality of the nuts from the several treatments. The information obtained in regard to soundness and the percentage of light colored meats is given in table 7. Comments concerning these tests will be made later in conjunction with other similar tests.

The comparative effectiveness of parathion and Systox in controlling the walnut aphid was also studied at Walnut Creek and at San Jose during 1953. The results were similar to those obtained at Linden except that in late seasons, the aphid populations in the Systox treatments did not increase to as high a level as they did at Linden. At Walnut Creek, a ½-pound treatment of Systox was compared with two applications of parathion, while at San Jose a ¾-pound dosage of Systox was checked against three applications of parathion. The quality of nuts from these treatments as determined by a cracking test is shown in table 7.

In 1954, aphicides were again used in combination with the codling moth spray at Linden. The kinds and the amounts of aphicides used, along with the degree of control obtained are given in table 3. Control of the walnut aphid was obtained with a single treatment of non-systemic aphicide. This was due to the fact that unusually high temperatures at critical periods in late June and again in August resulted in a high aphid mortality. The Systox treatments behaved much the same as in 1953. There was an indication of a direct relation between dosage and the residual action of the material. At all dosages, good control was obtained through August, but in September there was a rapid increase in the population. A marked increase also occurred in the non-systemic treatments. As in 1953, the control obtained with schradan was outstanding. Even at the lowest dosage, which amounted to 1½ pounds of technical material per acre, the aphids were almost completely absent on the last organized survey conducted on September 15. Spot checks made at later dates showed the schradan treatments to be nearly free of aphids.

**Table 3.—Aphicides[a] used in conjunction with the codling moth spray against the walnut aphid at Linden, California. 1954.**

| Aphicide and Pounds per Acre | Average Number of Aphids per Leaflet on[b] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | June 8 | June 18 | June 29 | July 15 | July 29 | Aug. 16 | Aug. 30 | Sept. 15 |
| 25% parathion W.P., 1 | 0.01 | 0.23 | 0.03 | 0.03 | 0.01 | 0.46 | 4.14 | 40.40 |
| 25% malathion W.P., 3 | 0.04 | 0.13 | 0.02 | 0.17 | 0.01 | 0.42 | 3.20 | 48.14 |
| 14% nicotine dry concentrate, 7 | 0.87 | 6.16 | 0.19 | 0.01 | 0.04 | 0.46 | 4.42 | 48.57 |
| BHC, 6% gamma isomer, 7 | 0.14 | 0.14 | 0.10 | 0.08 | 0.34 | 0.12 | 4.39 | 26.86 |
| Systox (actual) | | | | | | | | |
| 0.25 | 0.02 | 0.05 | 0.01 | 0.04 | 0.17 | 0.61 | 6.63 | 49.69 |
| 0.50 | 0.00 | 0.02 | 0.00 | 0.03 | 0.03 | 0.35 | 4.81 | 47.23 |
| 0.75 | 0.01 | 0.03 | 0.00 | 0.01 | 0.00 | 0.04 | 3.64 | 29.47 |
| 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.58 | 18.71 |
| Schradan (technical) | | | | | | | | |
| 1.5 | 0.02 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.11 |
| 2.0 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.04 |
| 2.5 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.02 |

[a] Applied May 4 to 7, in 200 gallons of water with an air carrier sprayer.
[b] Prior to treatment, the average number of aphids per leaflet on May 4 was 11.7. No aphids were found in any of the plots on May 12.

**Table 4.—Systox and parathion, when combined with the codling moth spray,[a] against the walnut aphid at Modesto, California. 1954.**

| Aphicide and Pounds per Acre | Average Number of Aphids per Leaflet on[b] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | June 11 | June 24 | June 30 | July 9 | July 21 | Aug. 5 | Aug. 23 | Sept. 16 |
| Systox (actual), 0.5 | 0.00 | 0.02 | 0.04 | 0.34 | 0.66 | 1.96 | 5.50 | 25.50 |
| 25% parathion W.P., 1[c] | 0.57 | 40.52 | 11.64[d] | 0.00 | 0.04 | 0.16 | 1.66 | 60.38 |

[a] Applied May 3 in 200 gallons of water with an air carrier sprayer.
[b] Prior to treatment, the average number of aphids per leaflet on May 3 was 1.08. No aphids found in the Systox-treated plot on May 12.
[c] A second application was made June 30, in 50 gallons of water per acre.
[d] Pre-treatment count.

At harvest the quality of the nuts from the different treatments was determined as shown in table 7.

At Modesto, another northern San Joaquin Valley locality, Systox and parathion were compared for aphid control. The treatments, dosages, and the degree of control obtained are given in table 4. The control obtained with Systox closely followed that recorded at Linden. Timely irrigations during unusually hot periods prevented any noticeable kill of the aphid due to heat. The control obtained with a single Systox treatment was much superior to that obtained with two applications of parathion. The drop in the aphid population in the parathion treatment following the June 24 survey was the result of a rapidly increasing predator population. The quality of the harvested nuts in the two treatments is given in table 7.

At Walnut Creek, which is located in a cooler, more coastal climate, Systox and schradan were compared with a small block of untreated trees (Table 5). The aphid population in the check was somewhat decreased by aphid treatments applied to surrounding orchards. Nevertheless, a sizeable aphid population developed, and the trees dripped with honeydew. Later the nut and leaf surfaces, covered with honeydew, turned black due to the growth of the sooty mold fungus. The systemic plots remained relatively free of aphids. Late in the season there was some increase in the populations in the Systox treatment, but to a lesser degree than that which occurred in the interior valley. The schradan treatment remained almost entirely free of aphids. The quality of the harvested nuts is shown in table 7.

Systox and schradan were compared in two orchards at San Jose (Table 6), an area located at the south end of the San Francisco Bay. Here the aphid control was similar to that obtained at Walnut Creek. However, in both orchards the increase of the aphid population in the Systox plots in late summer was much less than that which occurred at Walnut Creek. Again, the aphid was absent in the schradan treatments.

Orchard "B" was examined in late October, and the foliage in the schradan treatment was in near perfect condition. The trees looked as if they were in their prime, and the foliage had not begun to lose its color.

Orchard "A" was one where the walnut aphid resistance to parathion is known to occur (Michelbacher *et al.* 1954). During 1954 it was difficult to obtain control of the aphid with dosages of 25% parathion that ranged between 3 and 4 pounds wettable powder per acre. Yet, in plots removed only by a few rows of trees, Systox and

Table 5.—Systox and schradan used in conjunction with the codling moth spray,[a] against the walnut aphid at Walnut Creek, California. 1954.

| Aphicide and Pounds per Acre | Average Number of Aphids per Leaflet on[b] | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | May 18 | June 11 | June 18 | June 23 | June 29 | July 15 | July 29 | Aug. 9 | Aug. 26 | Sept. 8 | Sept. 22 |
| None | 9.29 | 6.86 | 46.59 | 21.87 | 22.94 | 13.52 | 0.08 | 0.02 | 0.75 | 3.98 | 17.17 |
| Systox (actual) 0.5 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.52 | 0.00 | 0.08 | 0.92 | 3.22 | 15.01 |
| Schradan (technical) 2 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 |

[a] Applied May 14 in 200 gallons of water with an air carrier sprayer.
[b] Prior to treatment, the average number of aphids per leaflet on May 4 was 7.17.

schradan resulted in highly satisfactory control. The Systox and schradan plots were located in the area of the orchard where resistance to parathion was demonstrated in 1953. The quality of the harvested nuts in the San Jose orchards is also shown in table 7.

FACTORS AFFECTING QUALITY OF NUTS.—The information in table 7 shows that there are a number of factors that influence the quality of nuts. Among the important ones that can be associated with the material contained in the table are climate, weather conditions, and the walnut aphid. There are others, but they do not play an important part in the information at hand. Cultural care can be important, but in these investigations, all orchards received from good to excellent care. Spider mites can also greatly reduce quality, but in none of the plots under discussion did they reach an economic level.

*Climate.*—All that is necessary is to compare nut quality obtained in the localities located in the San Joaquin Valley with that secured in the more coastal areas. Regardless of aphid control, the best quality is found in the location having the cooler climate. While some advantage shows up in soundness, the greatest difference is to be found in the lighter color of the nut meats. In the check plot at Walnut Creek, where a troublesome aphid population developed, 93.3 per cent of the nuts were sound and 70.3 per cent had light colored meats. This compares well with treatments in the interior Valley, where practically no aphids occurred, and far excells the parathion treatment at Modesto, where an aphid problem developed.

*Weather Conditions.*—The quality of the walnut crop is certainly influenced by weather. This is most apparent in the San Joaquin Valley. High temperatures have the tendency to lower quality and tend to obscure the value of aphid control. Adverse weather conditions in 1953 and 1954 resulted in a total loss of many exposed nuts and a marked reduction in quality of the remaining crop. In July, 1953, there were 14 days when the temperature reached more than 100° F. (mean maximum for the month 99° F.), and as a result it was estimated that 20 per cent of the developing nuts in the experimental orchard at Linden were completely destroyed due to sunburn. This occurred as well in treated plots that contained no aphids. Again in 1953, a few very hot days toward the end of June destroyed an estimated 20 per cent of the crop. Again this occurred in treated plots where no aphids could be found.

In 1952, weather conditions were not as unfavorable as they were in either 1953 or 1954. The data on the quality of nuts obtained from three treatments at Linden for that

Table 6.—Systox and schradan against the walnut aphid in two orchards at San Jose, California. 1954.

| Aphicide and Pounds per Acre | Average Number of Aphids per Leaflet on | | | | | | |
|---|---|---|---|---|---|---|---|
| | June 2 | June 11 | July 2 | July 19 | Aug. 9 | Aug. 26 | Sept. 16 |
| Orchard A[a,b] | | | | | | | |
| Systox (actual 0.75) | 0.00 | 0.00 | 0.00 | 0.01 | 0.16 | 0.95 | 3.95 |
| Schradan (technical) 2.5 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.02 |
| Orchard B[c] | | | | | | | |
| Systox (actual)[d] 0.5 | 0.01 | 0.00 | 0.00 | 0.00 | 0.12 | 0.51 | 6.25 |
| Systox (actual)[e] 0.75 | 0.00 | 0.00 | 0.00 | 0.00 | 0.07 | 0.84 | 1.60 |
| Schradan (actual)[e] 1.70 | 0.01 | 0.00 | 0.01 | 0.01 | 0.01 | 0.00 | 0.12 |

[a] Prior to treatment, the average number of aphids per leaflet was 6.61. Treatments applied May 20 in both orchards with air carrier sprayers. No aphids found in treated plots in either orchard May 26.
[b] Applied in 100 gallons of water per acre.
[c] Prior to treatment, the average number of aphids per leaflet was 5.69.
[d] Applied in 125 gallons of water per acre.
[e] Applied in combination with codling moth spray in 200 gallons of water per acre.

Table 7.—Quality of walnuts from the several aphicide treatments in different localities in northern California.[a]

| Aphicide and Pounds per Acre per Application | Quality of Nuts | | | | | |
|---|---|---|---|---|---|---|
| | Per Cent Sound | | | Per Cent Light Colored Meats | | |
| | 1952 | 1953 | 1954 | 1952 | 1953 | 1954 |
| *Linden* | | | | | | |
| 25% parathion W.P., 1[b] | 92.3 | 92.3 | 94.2[c] | 66.3 | 49.0 | 61.2 |
| 25% malathion W.P., 3[b] | — | 93.3 | 91.0[c] | — | 43.1 | 54.4 |
| 14% nicotine dry concentrate, 7[b] | 91.6 | 92.2 | 92.2[c] | 72.3 | 51.9 | 49.8 |
| Systox (actual) | | | | | | |
| 0.25 | — | 91.0 | 90.3 | — | 41.5 | 50.2 |
| 0.50 | — | 94.0 | 91.3 | — | 47.0 | 49.2 |
| 0.75 | — | 91.0 | 92.2 | — | 45.5 | 55.7 |
| 1.00 | — | 92.5 | 93.7 | — | 53.5 | 56.0 |
| 1.25 | 91.0 | 95.0 | — | 76.0 | 53.0 | — |
| Schradan (technical) | | | | | | |
| 1.5 | — | — | 91.2 | — | — | 58.0 |
| 2.0 | — | — | 94.0 | — | — | 56.0 |
| 2.5 | — | 93.5 | 94.3 | — | 49.0 | 68.3 |
| *Modesto* | | | | | | |
| 25% parathion W.P., 1[b] | — | — | 87.7 | — | — | 30.0 |
| Systox (actual) 0.5 | — | — | 96.0 | — | — | 55.0 |
| *Walnut Creek* | | | | | | |
| No treatment | — | — | 93.3 | — | — | 70.3 |
| Systox (actual) 0.5 | — | 96.7 | 96.7 | — | 86.7 | 84.3 |
| Schradan (technical) 2 | — | — | 97.3 | — | — | 85.7 |
| 25% parathion W.P., 1[b] | — | 93.7 | — | — | 74.7 | — |
| *San Jose* | | | | | | |
| *Orchard A*—Systox (actual) 0.75 | — | — | 97.0 | — | — | 71.7 |
| Schradan (technical) 2.5 | — | — | 98.7 | — | — | 75.7 |
| *Orchard B*—Systox (actual) 0.5 | — | — | 98.7 | — | — | 95.7 |
| Systox (actual) 0.75 | — | 98.0 | 98.0 | — | 92.0 | 97.0 |
| Schradan (technical) 1.7 | — | — | 99.3 | — | — | 98.0 |
| 25% parathion W.P., 1[d] | — | 98.0 | — | — | 93.0 | — |

[a] Based upon cracking an average of at least three 100-nut samples per plot or at least six 100-nut samples per treatment.
[b] Two applications.
[c] A single treatment: temperatures in 1954 were severe enough to control the aphid in midseason.
[d] Three applications.

year are included in table 7. While soundness was not greatly different than that obtained in 1953 and 1954, lightness in color of meats was much superior.

*Walnut Aphid.*—The information in table 7 shows that the walnut aphid can markedly reduce the quality of the walnut crop. At Modesto in the plot treated with parathion, a fairly large population developed in midseason, and the quality of the crop was considerably reduced below that in the Systox treatment, which was relatively free of aphid infestation. In general, in the interior valley, the quality of the nuts tended to follow the degree of aphid control. In 1952 this was fairly marked. Best control was obtained with Systox and poorest with parathion, and the quality of the nuts, particularly in regard to color, varied directly with aphid populations. In the cooler regions, the quality of the nuts in the plot receiving no treatment at Walnut Creek was markedly lower than that obtained in any of the treated plots either at Walnut Creek or at San Jose.

From the results, it appears that a certain amount of aphids can be tolerated. It has been felt that aphids late in the season cause little damage. However, large populations at this time certainly speed up the period when the trees drop their leaves. This may come too late to be of any real harm. More information on this should be sought. Schradan apparently has the ability to keep the trees free of aphids until late fall, and it is planned to continue to treat the same plots for a number of years to see if extending aphid control into late fall will result in a noticeable increase in production and quality of nuts.

*Systemic Insecticides.*—While Systox and schradan are very effective in controlling the walnut aphid, they have some limitations. Although Ortega (1953) reported Systox as being uninjurious to walnut in southern California, foliage injury has been detected where it has been applied to walnuts in northern California (Michelbacher & Bacon 1953). However, to the present time, this injury has not been associated with any reduction in the quality of the harvested crop. Foliage injury is most likely to occur where Systox is applied to young developing leaves. As a precaution, it should never be applied on any variety of walnut until the trees come into full leaf. Injury is less marked at lower dosages, and it appears that Systox should not be applied at more than $\frac{3}{4}$-pound of actual material per acre. Satisfactory control of the walnut aphid and spider mite can be obtained with dosages that range from $\frac{1}{4}$ to $\frac{1}{2}$ pound per acre. Systox apparently has no residual controlling action upon the young of the frosted scale, *Lecanium pruisosum* Coq. Systox also offers very little protection to foliage that is produced after the treatment is applied. Evidence obtained indicates that the residual action of Systox against the walnut aphid is longer in the cooler more coastal climate than in the hot interior San Joaquin Valley. Taste tests have shown that Systox does not impart an off-flavor to the nuts, and no residue problem is indicated where but a single application is made early in the season. The insecticide has been registered by the California State Department of Agriculture for use on walnuts in California.

Schradan results in exceptionally good control of the walnut aphid and spider mite. For best results it must be *evenly* and *thoroughly* applied. Also, evidence obtained during 1954 indicates that is should be applied before the foliage becomes too old. Unless modified by additional investigations, it is recommended that schradan be applied not later than the end of May or the first of June. To the present time, the lowest dosage used has been $1\frac{1}{2}$ pounds of technical material per acre. This amount has resulted in excellent control for the entire season, and evidence indicates that it might be effective at a dosage of 1 pound per acre. However, until this can be experimentally determined, the recommended amount to use per acre ranges from $1\frac{1}{2}$ to 2 pounds. At these rates, excellent control of Pacific mite as well as the walnut aphid can be expected, and indications are that the treatment is effective against the young of the frosted scale. No plant injury to walnuts has been detected, although injury to peanut has been reported by Arthur & Arant (1954). Taste tests have been conducted, and no off-flavor has been detected. Residue studies have been undertaken, and no serious problem is indicated. Schradan has been registered in California for use on walnuts by the California State Department of Agriculture.

EFFECT OF SUMMER TEMPERATURES UPON THE WALNUT APHID.—Many growers have long believed that high summer temperatures result in the destruction of many aphids. Investigations, however, have shown that the reduction in the aphid population that frequently occurs with the advent of hot weather is usually due to the action of natural enemies. Studies during 1954 showed that under certain conditions hot weather can result in high aphid mortality. This occurred in the experimental orchard at Linden. On two occasions unusually hot weather occurred there just before the orchard was to be irrigated. Under these dry conditions and heat, the aphid population was all but eliminated. During the first hot spell, some sunburning of the foliage took place. In near by orchards that were under irrigation or had recently been irrigated, the hot spells apparently did not adversely affect the aphid. Although it is established that aphids can be killed by hot summer temperatures, the control obtained is not without cost for the same temperatures result in a considerable loss of crop due to sunburn.

SUMMARY.—Many factors besides the walnut aphid may adversely affect the quality of walnuts. Important among these are the kind of cultural care given an orchard, other insects, spider mites, weather conditions, and climate.

The most critical period to control the walnut aphid is from May through August.

The climate of the more coastal areas favors increased quality. Unusual periods of hot weather, particularly in the hot interior Valleys, adversely affects quality and tends to equalize treatments.

Unusually high summer temperatures in association with low soil moisture resulted in a high mortality of the walnut aphid.

The systemic insecticides, Systox and schradan, gave better control of the walnut aphid than the non-systemic aphicides. Schardan outperformed Systox. Few aphids were found in late fall where single treatments of schradan were applied in May. Satisfactory control with schradan depends upon thorough coverage and, apparently, making the application before the walnut foliage becomes too mature.

Systox has been responsible for leaf injury and applica-

tions should not be made before walnut trees come into full leaf.

Both Systox and schradan gave excellent control of the walnut aphid in an orchard at San Jose, where the strain of aphid known to be resistant to parathion occurs.

Natural enemies are extremely important in controlling the walnut aphid.

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# DDT Tolerance by Lygus Bugs on Seed Alfalfa[1]

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From the time of the earliest commercial use of DDT in 1946 for the control of lygus bugs (mainly *Lygus hesperus* Knight) in California alfalfa seed fields, there have been persistent reports of inadequate control or complete failure of control. In general, it has been felt that, due to the habits and distribution of populations of lygus bugs in both cultivated and uncultivated areas, resistant populations would not develop. A number of other explanations for these failures have been offered including poor formulation of the insecticides, inadequate application, movements of adults, lack of penetration of heavy growth, and high summer temperatures. These factors in various combinations have undoubtedly contributed to the problem. In the interior desert regions during the hottest part of the year, especially when applied as a dust, DDT has given poor results. This may be logically explained by temperature effects as it is well known that with many insects DDT is more effective at lower temperatures than at high temperatures (Hoffman & Lindquist 1949, Menn 1954). These various factors, however, do not explain the situation which has developed recently in the alfalfa seed growing regions of Washington and California. In the former area, Menke (1954) reported indications of lygus bug resistance to DDT that were not correlated with temperature conditions. In most of California, during the period prior to 1952, it was customary to obtain a reduction of 95 per cent or better in 48 hours with the standard treatment of 5 per cent DDT with 50 per cent sulfur at 30 pounds per acre. More recently, especially in certain frequently treated areas, the reduction at 48 hours has been much less, and in many cases, adequate reduction may not occur until 4 days. In a few cases, the control has been completely inadequate and the fields have been retreated with heavier dosages or with other materials. To further analyze this situation studies were conducted in the San Joaquin Valley during the 1953 and 1954 seasons.

EXPERIMENTAL PROCEDURE.—Due to the fact that it is necessary to treat all alfalfa seed fields at least once each year it is impossible to obtain an untreated population of lygus bugs in alfalfa seed fields. As a result all check populations were obtained from small alfalfa hay fields near Bakersfield in an area in which there are no known DDT treatments on alfalfa and very few on cotton. All of the alfalfa seed field studies were in Kern County, California, and most of them were near Arvin, an area from which there have been numerous reports of lack of control with DDT. The lygus bugs were collected in the field by sweeps of a standard 15-inch insect net and placed in a screen cage. The injury from collecting the adults was kept low and the cages were quickly transported to the laboratory. The adult lygus bugs were aspirated from the cage and placed in cloth top cartons. They were then anesthetized with carbon dioxide to facilitate counting and placed in holding vials in groups of 25 regardless of sex. Bioassay vials modified from the type described by Hoskins & Messenger (1950), were treated with appropriate dosages of a standardized oil-DDT-mixture. The lygus bugs were exposed in the bioassay vials for 1 hour, the vials being rotated one-quarter turn every 15 minutes, and then transferred to holding cages. The holding cages contained moistened cotton and a piece of fresh string bean. All exposures and subsequent holding was at a control led temperature of 75° F. Mortality was determined at 24 hours, and the approximate LD50 was assessed with the aid of probit-log dosage paper. In the 1953 studies, some comparisons were made of dusts applied in a bell jar duster and of topical applications of DDT in oil.

1953 RESULTS.—In late August and September, the authors in cooperation with O. H. Fullmer and W. M. Hoskins made a rapid survey of the situation in Kern

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County. The LD50 at 24 hours, for lygus bugs from alfalfa hay fields near Bakersfield (never known to have been treated), was 46 μg, as determined by treatments with 5% dusts. Lygus from alfalfa seed fields near Arvin, which had been treated several times during the growing season were found to have an LD50 of 300 μg when tested in the same manner. Replicated tests in bioassay vials, where the lygus bugs were exposed by the methods described above under experimental methods, indicated a LD50 of 10 to 20 μg for lygus bugs from untreated alfalfa hay fields as compared to approximately 50 μg for those from treated alfalfa seed fields. Topical applications of DDT in oil gave readings indicating LD50's 10 times as great for bugs from alfalfa seed fields as compared to those from alfalfa hay. There was also some evidence that lygus bugs from the treated alfalfa seed fields were also slightly more tolerant of toxaphene.

1954 RESULTS.—In the 1954 season these studies were expanded. The LD50's of lygus bug populations in untreated alfalfa hay fields were followed from the middle of June until the middle of September, and simultaneously the LD50's of lygus bug populations in nine alfalfa seed fields were checked. The results of these analyses are summarized in figure 1. The LD50's of lygus bug populations in alfalfa seed fields tended to be higher than those in alfalfa hay fields. The large area of overlap is largely due to the fact that in early season the populations in alfalfa seed fields were the same to only twice as tolerant as the populations in alfalfa hay fields. With the progress of the season the LD50's increased in the seed fields but not in the hay fields, so that at the end of the season, the lygus bugs in alfalfa seed fields were three to five times as tolerant of DDT as were the lygus bugs in the alfalfa hay fields. This increase during the season is illustrated in figure 2. In this field the LD50 progressed from 15 μg on June 27 to about 50 μg in midseason and 70 μg in late season. Menke (1954) indicates the same picture as he found poorer results with July applications than with June applications. The steepening of the lines as the season progressed would appear to indicate that there is a screening out of the more susceptible bugs without a general increase in tolerance. This is in contrast with many results with house flies (Perry & Hoskins 1951) where the lines tend to be flatter for the resistant populations.

DISCUSSION OF DOSAGE—MORTALITY DATA.—These data are strongly suggestive that lygus bug populations in alfalfa seed fields in California have developed some degree of resistance to DDT. However, at this time the degree of resistance is low and apparently does not increase markedly from season to season. In addition, several other facts indicate that this interpretation should be used with caution. First, there have been no difficulties in obtaining lygus bug control with DDT in

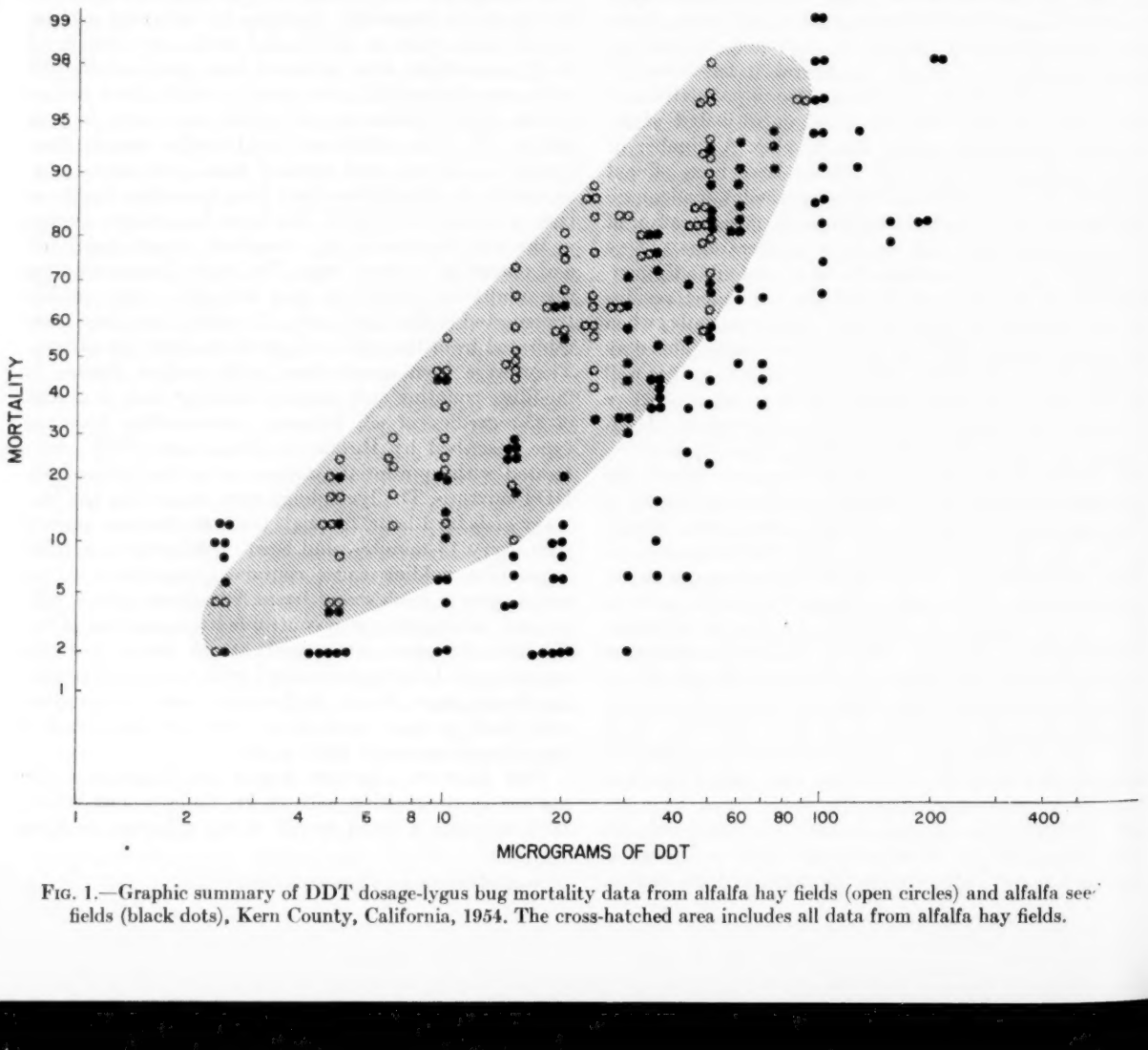


FIG. 1.—Graphic summary of DDT dosage-lygus bug mortality data from alfalfa hay fields (open circles) and alfalfa seed fields (black dots), Kern County, California, 1954. The cross-hatched area includes all data from alfalfa hay fields.

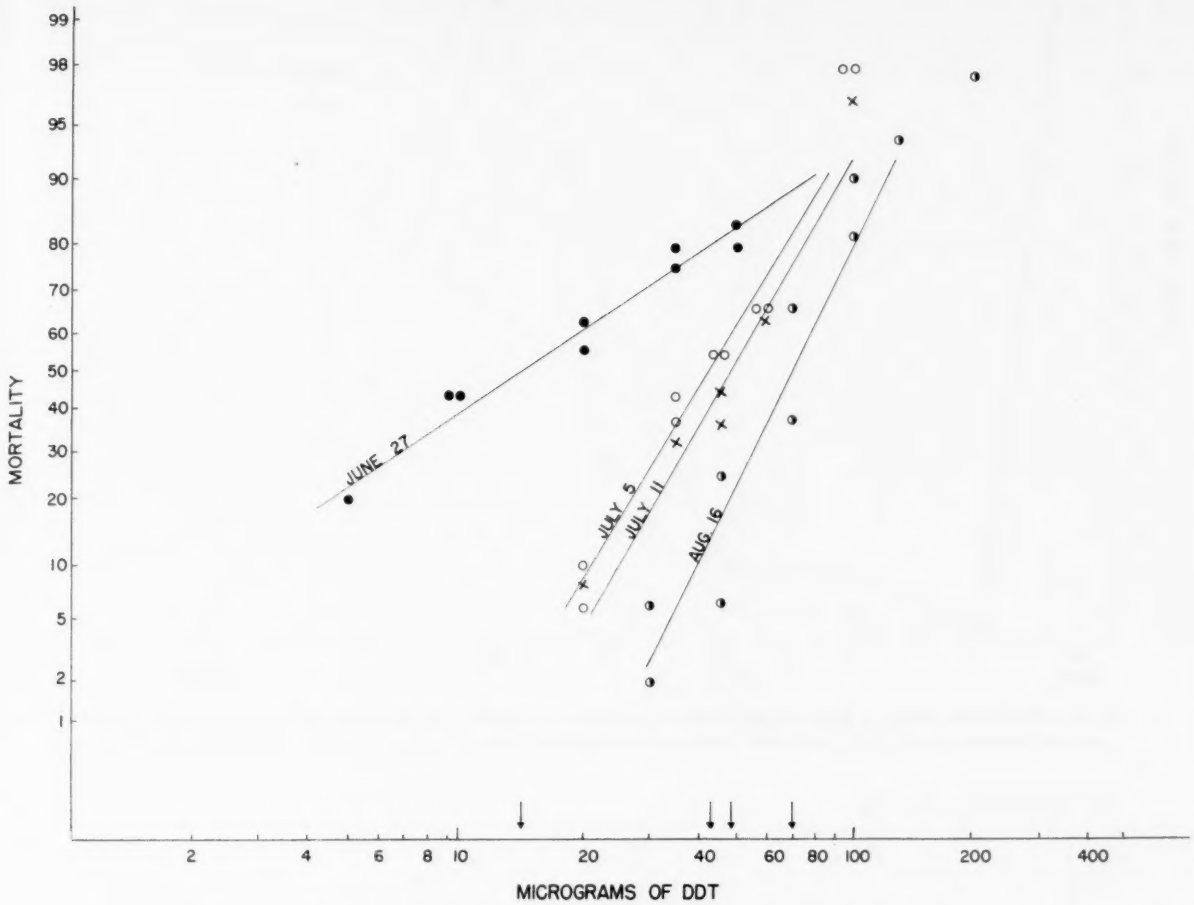


FIG. 2.—Change in LD50 of lygus bug populations in a single alfalfa seed field as season progressed. Kern County, California, 1954.

adjacent cotton fields. Second, the increased tolerance for DDT seemed to appear during the 1954 season in areas that were largely treated with toxaphene rather than DDT. Finally, limited data on populations in succulent regrowth in seed fields following harvest indicate a rapid loss of tolerance at the end of the season. In the field illustrated in figure 2, the LD50 dropped to 25 μg after harvest.

Undoubtedly, as indicated by the history of the past few years and the dosage-mortality data, there has been some development of resistance to DDT, but the field picture is complicated by the effects of temperature, increases in the use of toxaphene, and perhaps, host effects. This latter aspect merits additional investigation to analyze its importance and to distinguish between nutritional effects and those of the physical environment. The higher protein diet available in the seed fields might be sufficient alone to explain the differences. On the other hand, the seed fields are dry, hot, and dusty in late season and the plants are coarse and tough as compared to moist vigorously growing hay fields. This may result in a hardening of the individuals present or screening out of more susceptible individuals. It is also interesting in this regard that tests with dusts show greater changes in tolerances than tests with liquids.

DDT VERSUS TOXAPHENE.—These results raise the question as to the relative role of DDT and toxaphene as chemical controls for lygus bugs in alfalfa seed fields. In studies made during the period 1946 to 1948, DDT at 1.5 lbs/acre was definitely superior to toxaphene at 3 pounds per acre when judged by immediate control and duration of control. More recent studies indicate that the differences between these materials have become less or have disappeared. In figure 3, a comparison of DDT and toxaphene at standard rates in one of the so-called resistant areas is illustrated. Both materials gave satisfactory control. In the DDT plots the reduction was 99.0 per cent under the pretreatment count at 4 days, and at 18 days it was still 94.7 per cent; in the toxaphene plots the reduction was 99.6 per cent at 4 days, and at 18 days it was 97.8 per cent. After about 3 weeks the populations started to increase again. This increase was stopped by maturation of the field. The increase at the end of the season was due to concentration of lygus bugs into areas of regrowth. Although the difference was small at these dosages, toxaphene was definitely superior to DDT. In figure 4, the trends of the populations of the adults and nymphs in these same plots are presented. These data indicate that there was no important influence of migration into the plots and that the relative effectiveness of the materials is approximately the same on the adults and nymphs. Figure 5 presents similar data from another

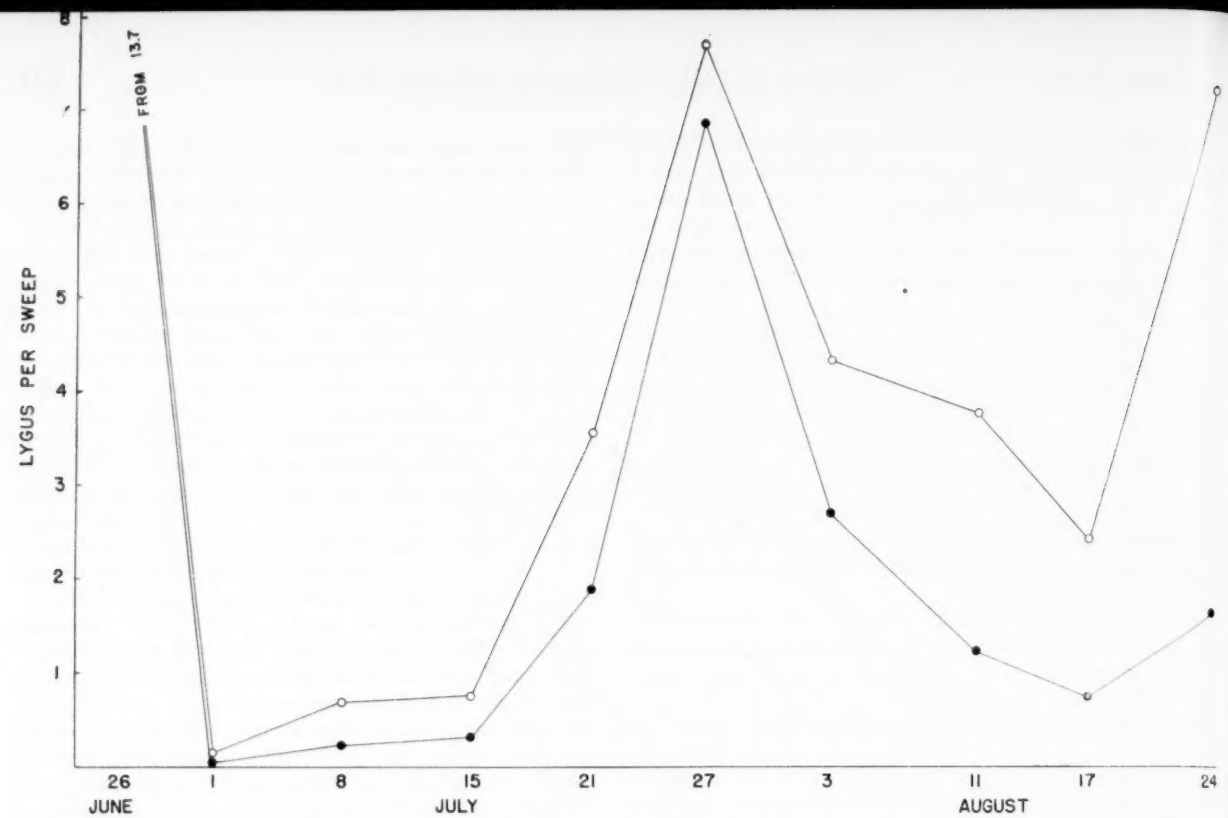


Fig. 3.—Population trends of lygus bug populations in areas of an alfalfa seed field treated by air with 5 per cent DDT–3 per cent aramite (open circles) and with 10 per cent toxaphene–3 per cent aramite (black dots) at 35 pounds per acre.

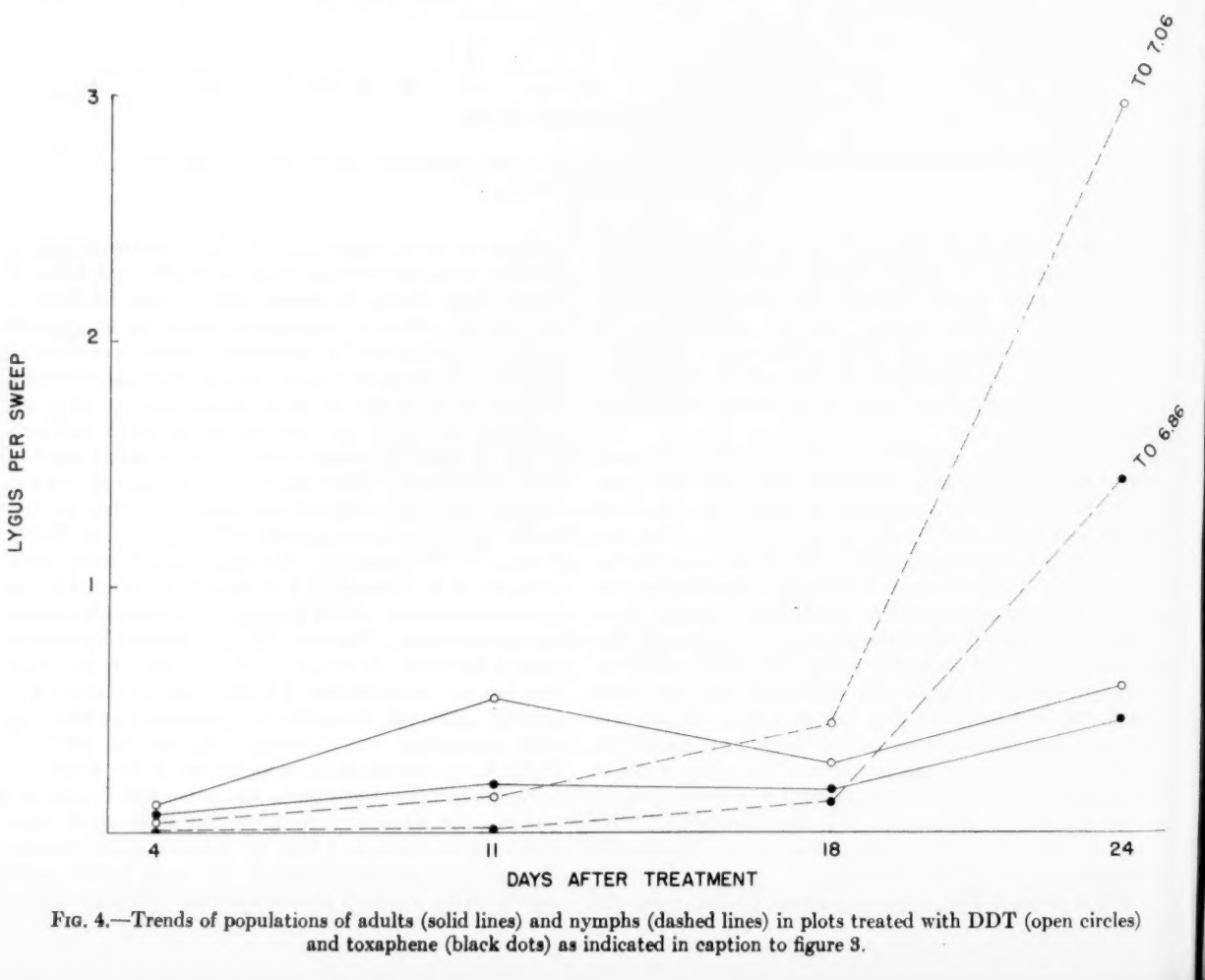


Fig. 4.—Trends of populations of adults (solid lines) and nymphs (dashed lines) in plots treated with DDT (open circles) and toxaphene (black dots) as indicated in caption to figure 3.

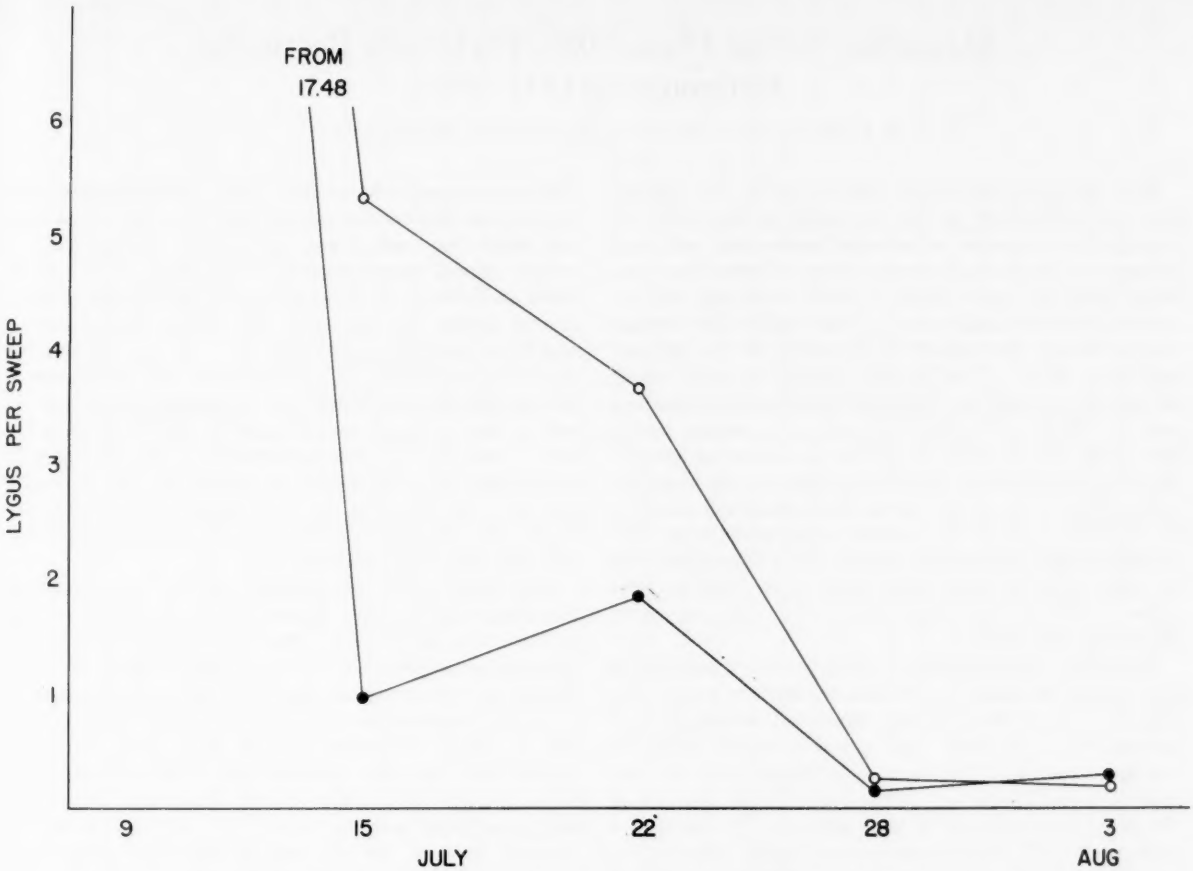


FIG. 5.—Population trends of lygus bug populations in areas of an alfalfa seed field treated by air with 5 per cent DDT–75 per cent sulfur (open circles) and 10 per cent toxaphene–50 per cent sulfur (black dots) at 35 pounds per acre.

field in the resistant area. In this case, the reduction in the DDT plots under the pretreatment count was only 69.6 per cent 5 days after treatment; while in the areas treated with toxaphene, it was 94.4 per cent. In this case the DDT treatment did not give satisfactory commercial control.

This information and the fact that toxaphene has a positive temperature coefficient (Hoffman & Lindquist 1949) favor the use of toxaphene over DDT in these areas especially from mid to late season and in the desert regions. On the other hand, at these dosages toxaphene is slower in its action than is DDT, it is more detrimental to the predator complex in alfalfa seed fields than is DDT (unpublished data of R. van den Bosch) and there is some evidence that tolerance for toxaphene is developing in a manner similar to that of DDT. In one test the LD50 for lygus bugs from alfalfa seed fields at 24 hours was 80 μg of toxaphene, while that of lygus bugs from the untreated alfalfa hay fields was 25 μg. Menke (1954) also indicated that recent results with toxaphene have been poorer than with DDT.

SUMMARY.—Laboratory and field investigations in 1953 and 1954 in Northern California indicate that the tolerance to DDT of lygus bugs has increased during recent years. Furthermore, this tolerance increases during the growth of the alfalfa seed crop. At harvest time the lygus bugs in alfalfa seed fields are three to four times as tolerant of DDT as those from untreated alfalfa hay fields or as they were at the beginning of the seed season. The field picture is complicated by other apsects such as the increased use of toxaphene, temperature effects, application problems, and probably host effects. Although there are some indications of increased tolerance to toxaphene, this material should probably be favored over DDT in the so-called resistant areas especially from mid to late season and in the desert areas.

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# Manitoba Nectar Flows 1924–1954, with Particular Reference to 1947–1954[1]

A. V. Mitchener,[2,3] *The University of Manitoba, Winnipeg, Canada*

Each summer from 1924 to 1954 inclusive, the Department of Entomology at The University of Manitoba has arranged for a number of selected beekeepers, scattered throughout Manitoba, to keep a colony of honey bees on a set of platform scales. Each of these beekeepers was requested to keep a daily record of the weight of an average normal colony throughout the 5 months of the summer beginning May 1. The largest number of scale colony records kept during any one year was 21 and the smallest was 10. Mitchener (1947) showed each annual nectar flow from 1924 to 1946 by means of a series of graphs. He also presented by means of graphs 5-year averaged nectar flows from 1925 to 1944. This paper will continue the record and show the annual nectar flows from 1947 to 1954 in Manitoba and 5-year averaged flows from 1945 to 1954 inclusive. Additional data from 1925 to 1954 inclusive will be used to provide further information on Manitoba nectar flows.

Methods.—Each beekeeper who became interested in this project provided his own set of platform scales. The Department of Entomology furnished mimeographed instructions each year and printed report forms in duplicate monthly, one copy to be returned to the Department of Entomology at the end of each month and the other to be retained by the beekeeper. The beekeeper took the weight of his scale colony daily, either in the morning or evening throughout the summer and showed on his report the date and weight of any equipment or honey added or taken from the colony. At the end of each season the Department of Entomology prepared performance graphs in duplicate for each scale colony. One copy was filed in the Department and the other sent to the beekeeper who prepared the record. A graph was prepared showing the average performance of all scale colony records for the season and a copy of this was also sent to each recorder.

Records.—Figure 1 and the upper half of figure 2 show the details of each annual nectar flow from 1947 to 1954 as averaged from all of the scale colony records kept for each year. The lower half of figure 2 shows the averaged nectar flow for the two 5-year periods, 1945–1949 and 1950–1954. The data for the flows of 1945 and 1946 were shown by Mitchener (1947). Figure 3 shows the duration of each annual nectar flow from 1925–1954 during which for each 5-day period, the averaged scale colony gained approximately 1 pound or more. Each black spot shows the 5-day period when the peak of each annual nectar flow occurred. The 15-day period during which the greatest annual gain was made is indicated by the arc. The number of scale colonies used each year is also shown. Table 1 shows the averaged annual gain as well as the averaged annual monthly gain in pounds for each 5-year period. The percentage of the total gain is shown also for each month. For example, the averaged gain per year for all of the scale colonies during July for the 5-year period 1925–1929 was 116.2 pounds which was 47.7 per cent of the total gain.

Discussion.—An examination of the annual nectar flows from 1947 to 1954, figures 1–2, shows that there was a continuous main nectar flow interrupted occasionally by weather conditions for a varying number of days. These interruptions were caused by lack of sunshine, by rain, cool weather, wind and no doubt by other factors not as yet as well recognized. In figure 2 the averaged nectar flow for each 5-year period shows a gradual starting point around the middle of June followed by a sharp rise from near the end of June until the peak was reached in July. At the end of July the nectar flow dropped off gradually until it was virtually over by the end of August. The graphs for individual years show seasonal variations for the beginnings, peaks, durations and ends of the nectar flows, but if beekeepers will plan their activities on the basis of the 5-year averages they will be ready to take advantage of any seasonal flow. The duration of the averaged nectar flow for the last two 5-year periods compares very favorably with the flows for the previous two 5-year periods as shown by Mitchener (1947).

Figure 3 shows that the most common time for the

[1] Accepted for publication February 28, 1955.

[2] Retired Aug. 31 and appointed Professor Emeritus in Entomology, Sept. 1, 1954.

[3] The writer is indebted to those beekeepers who for a few or many years have weighed and kept daily records of colony performances.

**Table 1.—Averaged gains for 5-year periods made by colonies of honey bees kept on platform scales from May 1 to Sept. 30, 1925–1954.**

| Five-Year Periods | Annual Total Pounds Gain for Averaged Scale Colony | Monthly Gain in Pounds for Averaged Scale Colony for Each 5 Year Period[a] | | | | |
|---|---|---|---|---|---|---|
| | | May | June | July | August | September |
| 1925–29 | 243.8 | 2.3 (1.0) | 13.6 (5.5) | 116.2 (47.7) | 105.2 (43.1) | 6.5 (2.6) |
| 1930–34 | 258.7 | 2.2 (0.9) | 25.9 (10.0) | 140.2 (54.2) | 80.4 (31.0) | 10.0 (3.9) |
| 1935–39 | 210.5 | 4.0 (1.9) | 23.2 (11.0) | 142.1 (67.5) | 39.8 (18.9) | 1.4 (0.7) |
| 1940–44 | 192.1 | 2.3 (1.2) | 27.9 (14.5) | 138.1 (71.9) | 23.8 (12.4) | 0.0 (0.0) |
| 1945–49 | 184.5 | 0.0 (0.0) | 12.8 (6.9) | 125.6 (68.1) | 46.1 (25.0) | 0.0 (0.0) |
| 1950–54 | 182.6 | 1.0 (0.5) | 13.1 (7.2) | 120.3 (65.9) | 48.2 (26.4) | 0.0 (0.0) |

[a] Monthly per cent gain given in parenthesis.

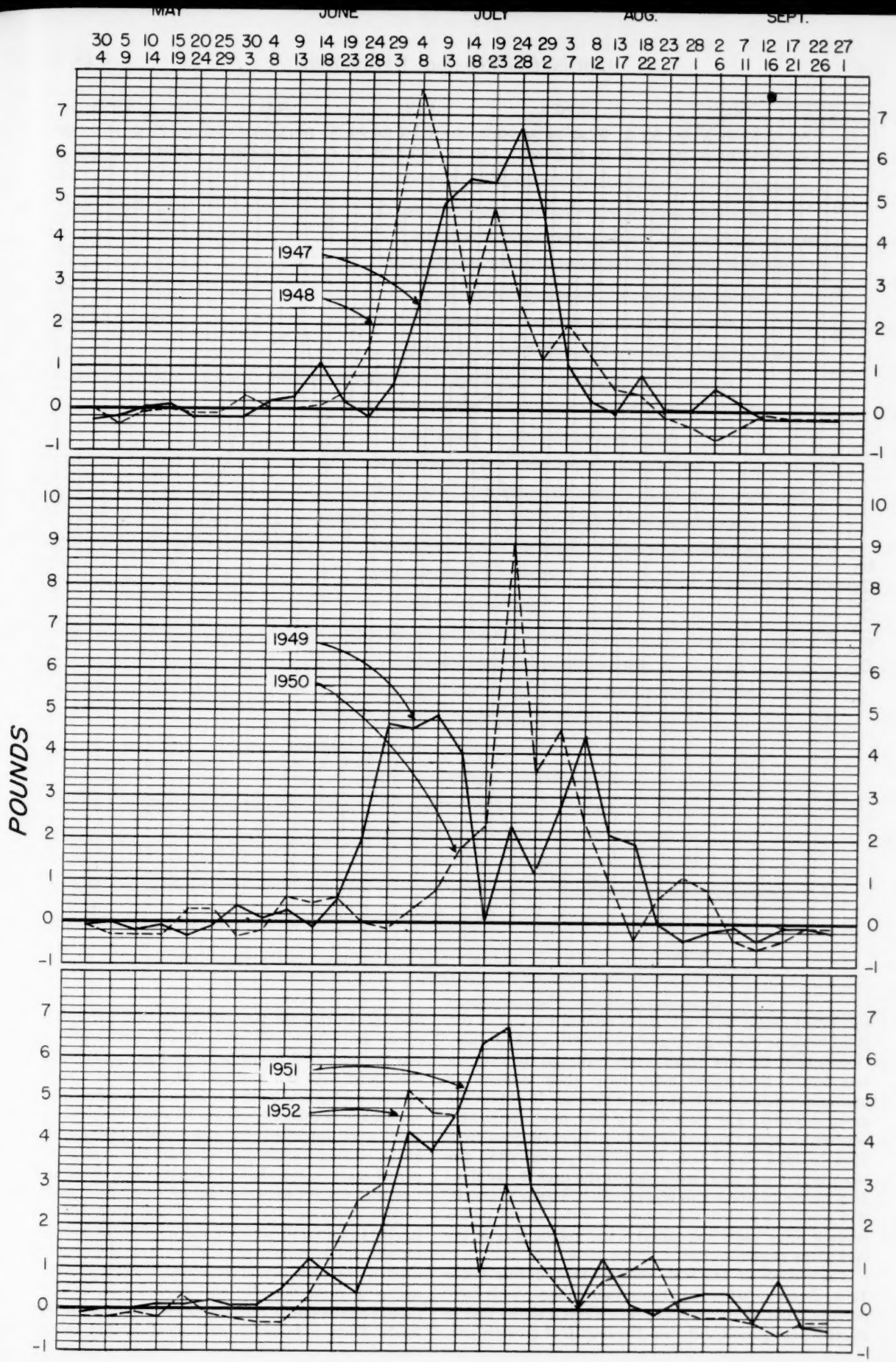


FIG. 1.—Manitoba nectar flows 1947–1952, inclusive.

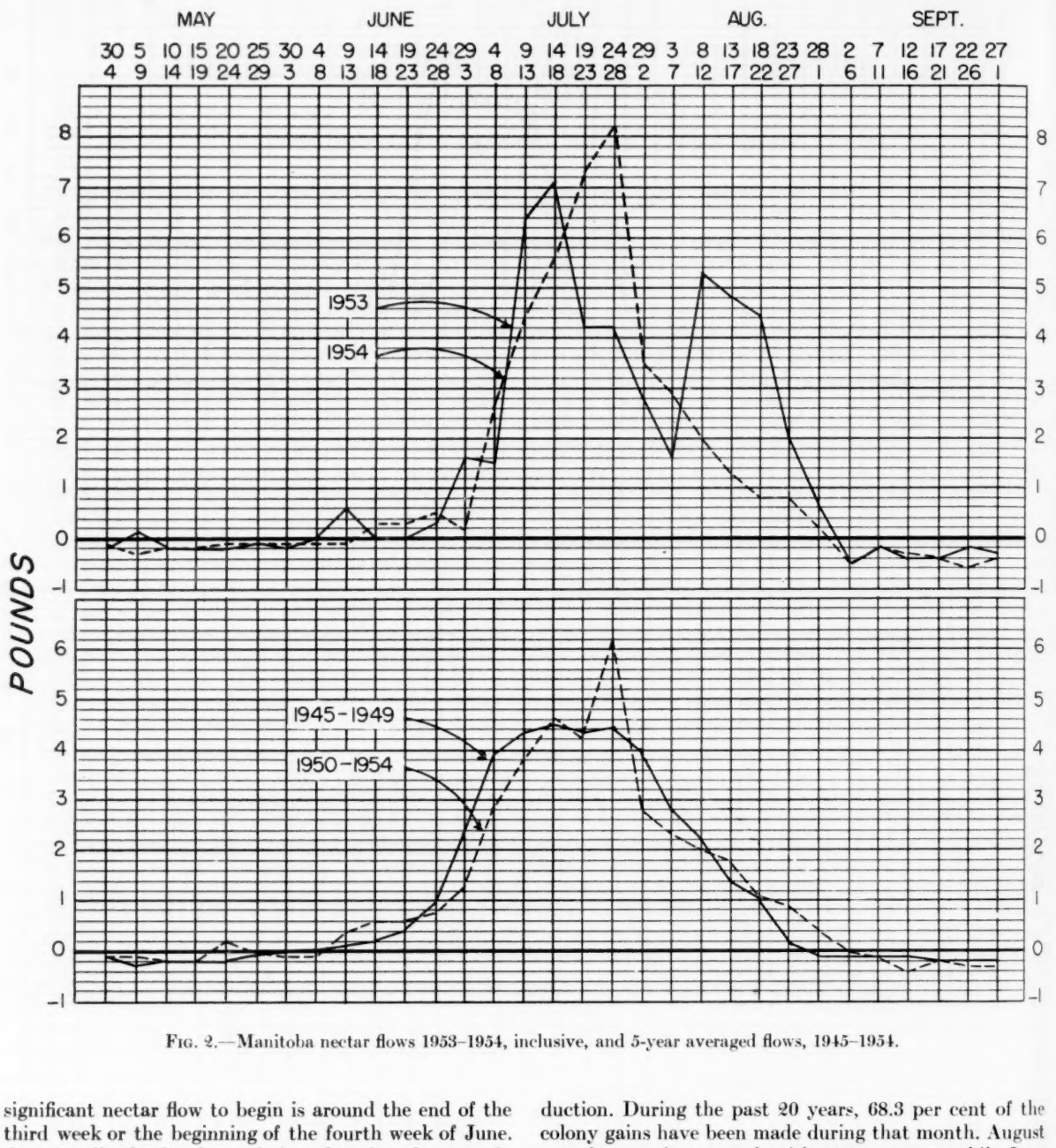


FIG. 2.—Manitoba nectar flows 1953–1954, inclusive, and 5-year averaged flows, 1945–1954.

significant nectar flow to begin is around the end of the third week or the beginning of the fourth week of June. Occasionally the flow began before then, but the net gain was small. Beekeepers must have their colonies in optimum condition at that time if they are to obtain the greatest yields. The peak of the flow most frequently occurred around the middle of July. In every year from 1924 to 1954 except one, the 15-day period when the most nectar was gathered included the peak 5-day flow. It is rather interesting to observe that in some years the flow reached a peak at the beginning of this 15-day period while in other years it occurred in the middle of or at the end of the period.

The records of 444 scale colonies kept during 1925–1954, shown in table 1, indicate that colony yields have decreased during the past 25 years. Table 1 shows that in every 5-year period, July was the month of greatest production. During the past 20 years, 68.3 per cent of the colony gains have been made during that month. August was the next best month with 20.7 per cent, while June was third with 9.9 per cent of the total gain. Little surplus nectar was stored in May. Although slight gains were made in early September by some beekeepers, these gains were cancelled by other scale colonies showing losses, so that for the past 15 years the averaged 5-year period scale colony showed no gain. The changed situation with respect to percentage of colony gain as between July and August for 1925–1934 and 1935–1944 is due largely to the fact that there was more sweet clover grown for seed and pasture in the earlier years. Mitchener (1948) showed the long period over which sweet clover yields nectar in Manitoba. He also showed that as the years passed alfalfa partly replaced sweet clover in the farmers' fields. There is however, an indication that the August

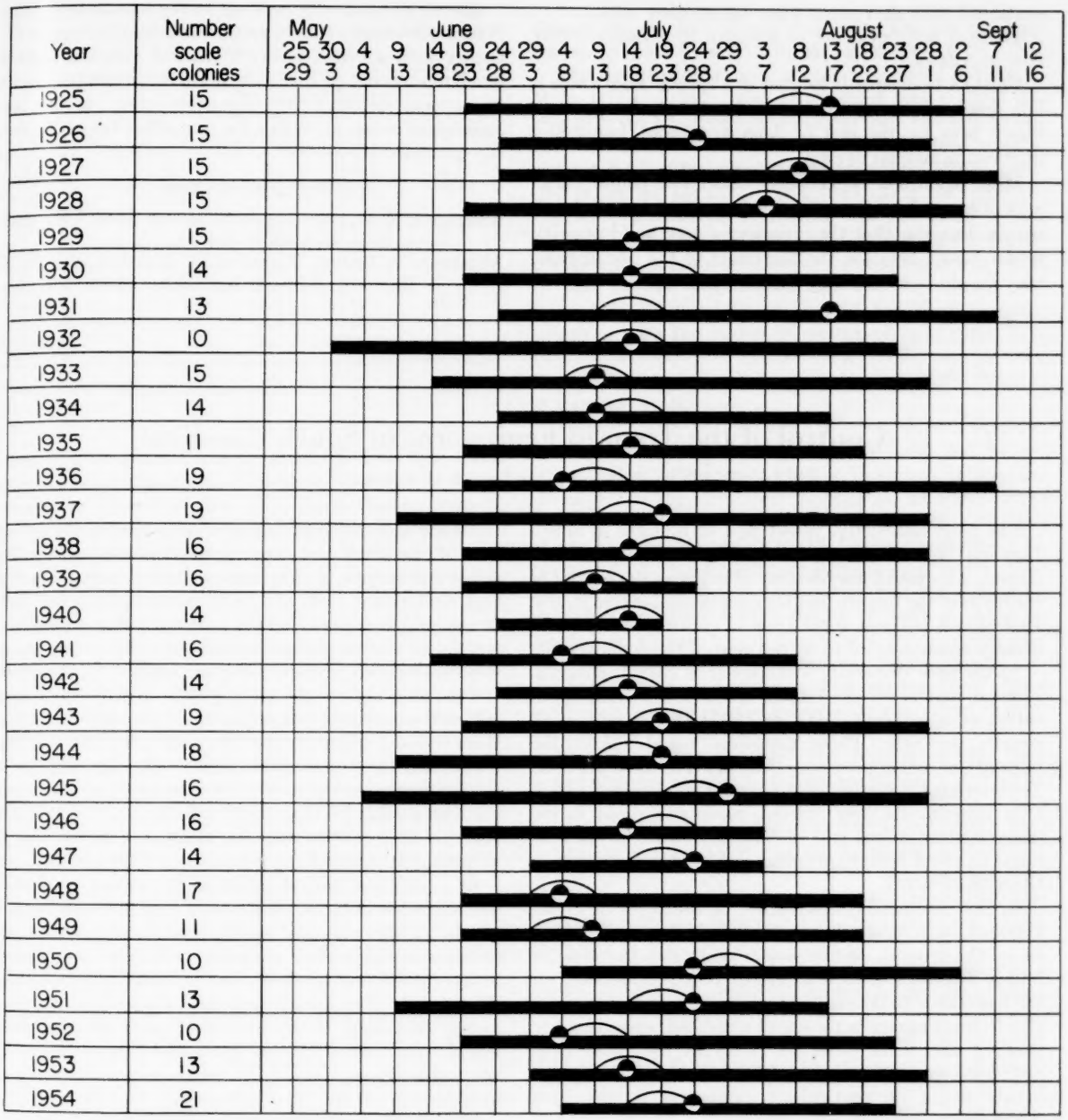


FIG. 3.—Nectar flows 1925–1954 are shown by bars during which the averaged scale colony gained 1 pound or more for each 5-day period. The circled points are the 5-day periods during which the peaks of the nectar flows were reached annually. The arcs cover the 15-day periods during which the averaged scale colony made the greatest gain.

nectar flow has increased during the past decade and at the expense of the June flow.

SUMMARY AND OBSERVATIONS.—During the past 10 years the beginning of the nectar flow as shown by the net gains made by the averaged scale colony varied from the third week in June until the first week in July and averaged near the beginning of the fourth week in June.

There has been one continuous main nectar flow other than the early stimulative flow each year. This main flow was interrupted at times by unfavorable weather conditions which prevented the honey bees from gathering nectar.

All but one of the 5-day flows as well as the best 15-day nectar flows with the exception of two came entirely in July during the past 23 years.

The peak of any nectar flow may come at the beginning, middle or end of the best 15-day nectar flow of the season.

During the past 20 years 68.3 per cent of all scale colony gains have been made in July, 20.7 per cent in August and 9.9 per cent in June.

During the past 10 years relatively small gains have been made by scale colonies after the end of the third week of August with the exception of 1953 when the flow

continued with decreasing vigor for another week.

There is some evidence of a return to a longer nectar flow in August.

Unless a beekeeper is located in a special area where a late flow may be expected, he may destroy his package honey bees by the end of August without losing any worthwhile amount of crop.

Most Manitoba beekeepers import two-pound packages of honey bees from the southern United States each spring. In order that these packages may build up with fielder honey bees for the beginning of the nectar flow, they should be received by the middle of April.

Queens shipped with package honey bees as well as replacement queens should be marked on the top of the thorax with a bright color. A marked queen is located much more easily on the frame when the beekeeper wishes to dequeen before destroying each colony in the late summer or when he wishes for any other reason to find the queen in any colony.

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# Control of the Tomato Fruitworm in South Carolina[1]

W. F. CHAMBERLAIN[2] and J. H. COCHRAN[3]

The most destructive insect pest of tomatos in South Carolina is the tomato fruitworm, *Heliothis armigera* (Hbn.). This insect may destroy as much as 80 per cent of the fruits of the tomato plants under favorable conditions. Destruction without some type of control measure will usually amount to 20 to 30 per cent of the tomato crop.

At the time this study was started in 1949, the recommended control for the tomato fruitworm was an application of 5 per cent DDT or DDD at the rate of 20 pounds per acre. These materials would reduce the infestation from approximately 30 per cent to 10 per cent. To determine if further control could be expected spray-type experiments were started. Some variations in the spray concentrations and the addition of additives were made to effect better spreading and sticking qualities in these experiments.

In the commercial cultivation of tomatoes in South Carolina, as in most other areas, the plants are allowed to lie on the ground. As the season progresses the mass of foliage increases to such an extent that it is difficult for the insecticide to penetrate through the foliage. One solution to this problem is the use of additional spreading and sticking agents in order to facilitate the more even distribution and retention of the insecticides. The sticking agents might be particularly important in this area where heavy summer rains occur.

METHODS.—The problem of disease control is much more acute in South Carolina than in some other areas of the United States, and this fact complicates the problem of insect control. In all the experiments reported in this study, a heavy application of fungicide was applied. Usually a fixed copper fungicide at the rate of 1½ pounds active copper per 100 gallons of water was applied every 5 days for the control of early and late tomato blight. To reduce wilt damage the wilt resistant varieties, Marglobe and Rutgers, were used in the tests.

Tests were conducted during the late spring and early fall because the hot weather in midsummer normally greatly reduces setting of the blossoms. One exception was made when one test was conducted on a small planting of tomatoes during the summer of 1950.

All the field experiments with sprays, with the exception of one small test, were conducted using a 3-gallon compression sprayer. Experiments were conducted on 3 to 5 randomized plots of 6 to 12 tomato plants per plot. In applying the sprays, an attempt was made to apply the equivalent of 100 gallons to the acre. When the plants were young, the quantity of spray applied was less than 100 gallons; but on the older plants slightly more than 100 gallons per acre was applied. The number of applications varied depending upon the growth conditions of the plants and the design of the experiment. Usually 3 to 6 applications were made. Counts were made on the ripening fruit so that pickings were necessary once a week for a period of 4 to 5 weeks. The number of fruits used in obtaining data varied from 75 to over 1,000 per test.

In a series of laboratory tests experiments were conducted to determine the degree of injury to young tomato plants by the various formulations tested in the field. In these experiments a potted tomato plant was placed on a turntable and sprayed with 5 cc. of the spray solution. The amount of spray used was determined to be approximately equivalent to the amount of spray this size plant would have received in the field. The spray application was made by compressed air passing over the tip of a hypodermic needle. The hypodermic needle was connected to the reservoir containing the desired quantity of the spray solution.

RESULTS.—*1949 Field experiments.*—In the field tests conducted during 1949 a comparison was made of the effectiveness of DDT and parathion dusts against DDT, DDD, dieldrin, methoxychlor, aldrin, and parathion sprays. The rates of application and results obtained in this experiment are recorded in table 1. The insecticides were applied on June 9, June 20, July 1, and July 20 and indicated that DDD and dieldrin gave the best control. There was no conclusive evidence as to whether the

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[2] Associate Entomologist.

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Table 1.—Insecticide tests against the tomato fruitworm in replicated plots treated four times. 1949.

| Insecticide | Dosage[a] | Number of Fruit | | Per Cent Infested |
|---|---|---|---|---|
| | | Infested | Sound | |
| DDD | 1 | 62 | 895 | 6.9 |
| Dieldrin | 0.25 | 75 | 901 | 8.1 |
| DDT, 5% dust (20 lbs.) | | 109 | 1,046 | 9.5 |
| DDT | 1 | 138 | 919 | 13.4 |
| Methoxychlor | 1 | 173 | 796 | 13.4 |
| Aldrin | 0.25 | 219 | 954 | 17.5 |
| Parathion | 0.25 | 206 | 734 | 20.3 |
| Parathion, 1% | | 269 | 716 | 27.2 |
| Untreated | | 382 | 705 | 35.7 |

[a] Pounds of active ingredient (applied in the form of a wettable powder) per 100 gallons of water.

spray or dust method was the most effective. The DDT dust was slightly better than the spray, but the parathion spray was better than the dust. The reduction from 35 per cent infestation in the check to below 7 per cent infestation with the DDT treatment is a very significant reduction, but from the standpoint of the canner, a further reduction is needed.

*1950 Field Experiments.*—The purpose of the experiments conducted during 1950 was to determine the degree of control that could be obtained with some of the materials tested in 1949, at different times during the season. Four plantings of tomatoes were made during the 1950 season to show the effect of time and degree of infestation. The plantings were made 2 weeks apart starting with the first field setting on May 1. Because of the more favorable growth conditions of the second and third plantings, the first application of sprays on these two plantings occurred soon after the first application of spray on the first planting. Sprays were applied on the first planting on May 27 and June 7, 13, and 27. Spray applications on the second planting were made on May 30, June 7, 13, 27, and July 17. Sprays were applied to the third planting on June 7, 13, 27, July 17 and August 4. The last planting was sprayed on June 27, July 17, and August 4.

Table 2.—Tomato fruitworm control with insecticides applied at various times during 1950 at Clemson, S. C.

| Insecticide[a] | Date of 1st Application | Number of Fruit | | Per Cent Infested | Per Cent Control |
|---|---|---|---|---|---|
| | | Sound | Infested | | |
| Dilan 50%, 2 | May 27 | 590 | 95 | 13.9 | 59.0 |
| TDE 50%, 2 | May 27 | 597 | 94 | 13.6 | 59.9 |
| DDT 50%, 2 | May 27 | 532 | 72 | 11.9 | 64.8 |
| Dieldrin 18%, 5.5 | May 27 | 618 | 75 | 10.8 | 68.2 |
| Untreated[b] | | 1,902 | 975 | 33.9 | |
| Dilan 50%, 2 | May 30 | 460 | 48 | 9.4 | 59.1 |
| TDE 50%, 2 | May 30 | 503 | 66 | 11.6 | 54.3 |
| DDT 50%, 2 | May 30 | 489 | 52 | 10.6 | 58.3 |
| Dieldrin 18%, 5.5 | May 30 | 476 | 54 | 11.3 | 55.5 |
| Untreated[b] | | 1,390 | 472 | 25.4 | |
| Dilan 50%, 2 | June 7 | 269 | 32 | 10.6 | 48.0 |
| TDE 50%, 2 | June 7 | 398 | 46 | 10.4 | 49.0 |
| DDT 50%, 2 | June 7 | 463 | 56 | 10.8 | 47.0 |
| Dieldrin 18%, 5.5 | June 7 | 415 | 35 | 7.8 | 61.7 |
| Untreated[b] | | 1,044 | 268 | 20.4 | |
| Dilan 50%, 2 | June 27 | 197 | 13 | 6.2 | 75.2 |
| TDE 50%, 2 | June 27 | 232 | 40 | 14.8 | 40.8 |
| DDT 50%, 2 | June 27 | 184 | 35 | 16.0 | 36.0 |
| Dieldrin 18%, 5.5 | June 27 | 273 | 37 | 11.9 | 52.4 |
| Untreated[b] | | 971 | 323 | 25.0 | |

[a] Pounds of wettable powder used per 100 gallons of water.
[b] Contains four times as many plots as treatments.

The results of this series of tests are shown in table 2. With DDT, dieldrin, and DDD there was a slight decrease in the effectiveness of control from the first to the fourth planting. With Dilan the control obtained was the same in the first two plantings, less the third planting and best in the last planting. The infestation in the tomatoes started at a relatively high level, was less in the second planting, and lowest in the third planting. In the fourth planting the natural infestation increased and was equal to that in the second planting. The decrease in the infestation exhibited by the second and third planting coincides with the period of silking of field corn. It is thought that earworm moths were attracted more to corn than to tomatoes, resulting in a decrease of the infestation on tomatoes.

The results of the 1949 and 1950 tests showed that the infestation of the tomato fruitworm could not be reduced below 5 per cent when a moderate infestation developed in the untreated check plots. In order to reduce the infestation below 5 per cent, the concentration of the insecticides tested in 1951 was increased to $1\frac{1}{2}$ pounds of active ingredient per 100 gallons of water. This amount had been used in some other areas of the country in order to obtain a high degree of control. Another purpose of the 1951 experiments was to determine the value of emulsions and whether they injured plants under South Carolina conditions. The concentration of the insecticide applied as an emulsion, was equivalent to that applied as a wettable powder.

*1951 Field Experiments.*—The results of the 1951 tests are shown in table 3. All the insecticides tested in the first experiment gave very good control. No test had more than 1 per cent infestation, but an important consideration was that there was only 7.2 per cent infestation in the untreated checks. The control obtained with the emulsions was equivalent to that obtained with the wettable powders. No injury to the plants was noted from any of the emulsions.

The results of the second group of tests in 1951 are also shown in table 3, In order to increase the chances of plant injury, a number of the later 1951 tests were conducted with added oils. A high degree of control was obtained with all the test materials. No economically significant differences were obtained between the tests with the oils and without oils. The wettable toxaphene gave slight better control than the emulsifiable toxaphene, but the difference is probably not significant. In three of the tests the plants were injured. All three cases of injury resulted from a combination of the 40 per cent toxaphene wettable powder with oil. The combinations of the toxaphene with 1 gallon of emulsifiable oil or $\frac{1}{4}$ gallon of emulsifiable oil paste caused slight injury while the combination with 1 gallon of emulsifiable oil paste resulted in moderate injury. No combination of oil and insecticide emulsion caused injury. A possible explanation of the injury was that the oil tended to be absorbed by the dust particles in the wettable powder and thus increased the local concentration. It was also noted that only the commercially prepared emulsifiable oils caused injury. The non-emuslifiable oils and the emulsions prepared in the Clemson laboratory did not cause injury. The cause

**Table 3.—Tests with wettable powders, emulsions, and oils for control of the tomato fruitworm (five applications), 1951.**

| Formulation[a] | Number of Fruit | | Per Cent Infested |
|---|---|---|---|
| | Infested | Sound | |
| *Series Starting June 12* | | | |
| TDE 50%, 3 W | 0 | 233 | 0.0 |
| Dilan 50%, 3 W | 2 | 332 | 0.6 |
| DDT 50%, 3 W | 0 | 330 | 0.0 |
| Toxaphene 72%, 2 qts., Em. | 0 | 220 | 0.0 |
| DDT 25%, 3 qts., Em. | 0 | 222 | 0.0 |
| CS-728[b] 25%, 3 qts., Em. | 1 | 285 | 0.4 |
| TDE, 25% 3 qts., Em. | 0 | 328 | 0.0 |
| Untreated | 22 | 306 | 7.2 |
| *Series Starting June 28* | | | |
| Toxaphene 40%, 7.5 W | 3 | 225 | 1.3 |
| Toxaphene 40%, 7.5 W+1 gal. Em. oil[c] | 1 | 215 | 0.5 |
| Toxaphene 40%, 7.5 W+1 gal. Em. oil paste[d] | 4 | 150 | 2.6 |
| Toxaphene 40%, 7.5 W+0.25 gal. em. oil paste | 2 | 164 | 1.2 |
| Toxaphene 40%, 7.5 W+1 pint spreader-sticker[e] | 3 | 229 | 1.3 |
| Toxaphene 40%, 7.5 W+1 gal. Em. Marcol GX[f] | 2 | 246 | 0.8 |
| Toxaphene 72%, 2 qts., Em. | 13 | 305 | 4.0 |
| Toxaphene 72%, 2 qts., Em.+1.5 gal. Marcol GX | 4 | 209 | 1.9 |
| Toxaphene 72%, 2 qts., Em.+0.5 gal. Marcol GX | 3 | 213 | 1.4 |
| Toxaphene 72%, 2 qts., Em.+1.5 gal. Solvaspray 100[g] | 8 | 254 | 3.0 |
| Toxaphene 72%, 2 qts., Em.+0.5 gal. Solvaspray 100 | 5 | 258 | 1.9 |
| DDT 25%, 3 qts., Em. | 6 | 325 | 1.8 |
| DDT 25%, 3 qts., Em.+1.5 gal. Marcol GX | 2 | 170 | 1.2 |
| DDT 25%, 3 qts., Em.+0.5 gal. Marcol GX | 4 | 256 | 1.5 |
| DDT 25%, 3 qts., Em.+1.5 gal. Solvaspray 100 | 5 | 223 | 2.2 |
| DDT 25%, 3 qts., Em.+0.5 gal. Solvaspray 100 | 0 | 233 | 0.0 |
| Untreated | 45 | 262 | 14.6 |

[a] Insecticides and adjuvants per 100 gallons of water designated as follows: W, pounds of wettable powder; Em., emulsion.
[b] 2-nitro-1-phenyl 1-p-chlorophenyl butane.
[c] California Spray Chemical Corporation. Volck Oil Spray.
[d] California Spray Chemical Corporation. Florida Volck Paste Emulsion.
[e] E. I. DuPont de Nemours, Inc.
[f] Esso Standard Oil Company, White Oil, Saybolt, Universal Viscosity at 100° F. 65–75 sec.
[g] Socony-Vacuum Oil Company, Inc. Isoparaffinic horticultural base oil.

of the injury may therefore have been due to the different types of oil used or to the emulsifying agent in the commercial preparation.

A slight reduction in yield was obtained where the injury was of a moderate extent. In one case, where a slight injury was noted, there was also a reduction in yield. This fact may be significant, but it may also indicate a reduction due to disease. The natural infestation in these tests did not equal that recorded in either the 1949 or 1950 tests.

One small test was conducted during 1951 using orchard-type, high pressure equipment. The results of this test are shown in table 4. Because of the high degree of control obtained with the compression-tank applied sprays and the relatively low natural infestations, no significant difference between the two means of application could be noted. No plant injury was noted.

**Table 4.—Tests against the tomato fruitworm with high pressure sprayer, five applications, starting June 28, 1951.**

| Insecticide[a] | Number of Fruit | | Per Cent Infested |
|---|---|---|---|
| | Infested | Sound | |
| DDT | 0 | 215 | 0.0 |
| TDE | 3 | 251 | 1.2 |
| Dilan | 1 | 311 | 0.3 |
| Untreated | 45 | 262 | 14.6 |

[a] Wettable powder, containing 50% of the active ingredient, at the rate of 3 pounds per 100 gallons of water was used.

*1952 Field Experiments.*—Because of the relatively low natural infestation occurring in both the 1951 experiments, it was decided to conduct similar experiments during 1952. To be sure of a higher infestation, the 1952 tests were conducted during the fall when the infestation is normally much greater. Because of an early frost, only one picking of the tomatoes was possible. The results of the 1952 tests are recorded in table 5. The natural infestation was at a relatively high level, and this condition probably balanced the reduction in yield caused by the frost.

No plant injury from any of the insecticide formulations was noted. It may be that the cooler weather during the fall reduced the chances of injury from materials that would normally cause injury during the hot summer. With the higher infestation recorded in this experiment, some differences in effectiveness of the insecticides resulted. Methoxychlor gave the poorest control while chlordane and toxaphene gave only fair control. The DDD, DDT, and Dilan were again the best materials

**Table 5.—Tests with wettable powders, dusts, emulsions, oils, and additives for control of the tomato fruitworm.**

| Formulation[a] | Number of Fruit | | Per Cent Infested |
|---|---|---|---|
| | Infested | Sound | |
| *Series Starting September 10, 1952*[b] | | | |
| DDT 50%, 3 W | 0 | 78 | 30.1 |
| DDT 50%, 3 W+1 gal. Solvaspray 100 | 0 | 55 | 0.0 |
| DDT 50%, 3 W+1 gal. Em. oil paste | 0 | 76 | 0.0 |
| DDT 50%, 3 W+1 gal. Superla No. 13 Mineral Oil[c] | 0 | 54 | 0.0 |
| DDT 50%, 3 W+0.8 lb. spreader sticker | 2 | 100 | 2.0 |
| DDT 50%, 3 W+0.8 lb. National sticker[d] | 1 | 62 | 1.6 |
| DDT 50%, 3 W+0.8 lb. Santomerse[e] | 0 | 90 | 0.0 |
| Dilan 50%, 3 W | 1 | 61 | 1.6 |
| DDT 25%, 3 qts., Em. | 2 | 83 | 2.4 |
| DDT 25%, 3 qts., Em.+1 gal. Solvaspray 100 | 4 | 90 | 4.2 |
| DDT 25%, 3 qts., Em.+1 gal. Em. oil paste | 0 | 72 | 0.0 |
| DDT 25%, 3 qts., Em.+1 gal. superla mineral oil | 0 | 68 | 0.0 |
| DDT 25%, 3 qts., Em.+0.8 lb. spreader sticker | 0 | 92 | 0.0 |
| DDT 25%, 3 qts., Em.+0.8 lb. National sticker | 2 | 72 | 2.7 |
| DDT 25%, 3 qts., Em.+0.8 lb. Santomerse | 0 | 70 | 0.0 |
| DDD 25%, 3 qts., Em. | 0 | 68 | 0.0 |
| Dilan 25%, 3 qts., Em. | 0 | 58 | 0.0 |
| Chlordane 60%, 1 qt., Em. | 4 | 58 | 6.5 |
| Toxaphene 60%, 2 qts., Em. | 4 | 58 | 6.5 |
| Methoxychlor 25%, 3 qts., Em. | 10 | 78 | 11.4 |
| Untreated | 28 | 65 | 30.1 |
| *Series Starting August 6, 1953*[f] | | | |
| DDT 5% dust | 1 | 151 | 0.6 |
| DDD 5% dust | 1 | 172 | 0.6 |
| Dilan 5% dust | 9 | 181 | 4.7 |
| DDT 50%, 3 W | 6 | 242 | 2.0 |
| DDT 50%, 3 W+4.2 lbs. Veegum[g] | 2 | 124 | 1.6 |
| DDT 50%, 3 W+0.83 lbs. Santomerse | 0 | 133 | 0.0 |
| DDT 50%, 3 W+0.5 pt. spreader sticker | 0 | 183 | 0.0 |
| DDT 50%, 3 W+8.3 lbs. Marcol GX | 0 | 94 | 0.0 |
| DDT 50%, 3 W+4.2 lbs. Emcol H77[h] | 1 | 160 | 0.6 |
| DDT 25%, 3 qts., Em. | 1 | 158 | 0.6 |
| DDT 25%, 3 qts., Em.+4.2 lbs. Veegum | 1 | 206 | 0.5 |
| DDT 25%, 3 qts., Em.+0.83 lb. Santomerse | 0 | 112 | 0.0 |
| DDT 25%, 3 qts., Em.+0.5 pt., spreader sticker | 0 | 145 | 0.0 |
| DDT 25%, 3 qts., Em.+8.3 lbs. Marcol GX | 0 | 122 | 0.0 |
| DDT 25%, 3 qts., Em.+4.2 lbs. Emcol H77 | 0 | 107 | 0.0 |
| Untreated (14 replicates) | 326 | 732 | 30.8 |

[a] Insecticides and adjuvants per 100 gallons of water designated as follows: W, pounds of wettable powder; Em., emulsion.
[b] Two replicates, three applications.
[c] Esso Standard Oil Company, a superior grade horticultural oil.
[d] National Sugar Refining Company, a sugar by-product.
[e] Monsanto Chemical Company, an alkyl aryl sodium sulfonate.
[f] Three replicates, four applications.
[g] R. T. Vanderbilt Company, a complex colloidal magnesium aluminum silicate.
[h] Emulsol Corporation, a blend of polyalcohol carboxylic esters and sulfonated oils.

for control of the tomato fruitworm. There was a slight difference in the amount of toxaphene used as compared with the earlier tests. This may have been responsible for its reduced efficiency. The addition of the various additives to the DDT did not appear to be necessary when the DDT was used at 1½ pounds per 100 gallons.

*1953 Field Experiments.*—The experiments on the use of additives to increase the value of the insecticides were continued in 1953. In addition to the spray formulations, dust applications were made with DDT, DDD, and Dilan at the rate of 50 pounds per acre. Applications were made every 2 weeks beginning when the first blooms fell from the plants. The experiments were conducted during the fall season and the results confirm those obtained in 1952 (Table 5). All of the combinations of DDT sticking or wetting agents were slightly superior to DDT alone, but not enough to warrant recommending their use in a practical control program. No differences were indicated by different sticking and wetting agents, particularly because of the high degree of control obtained with the DDT alone. An experiment conducted with a lower concentration of DDT with added sticking and wetting agents is indicated as a result of these tests. No plant injury was noted from any of the 1953 formulations. Five per cent DDT or DDD dusts when used at the rate of 50 pounds per acre will apparently give as good control as 3 pounds of 50 per cent wettable powder. The Dilan dust was inferior to the DDT or DDD dusts.

*Laboratory Experiments.*—The results of laboratory experiments on burning showed that the only material that caused consistent burning was a 25 per cent DDT emulsion at the rate of either 3 or 6 quarts per 100 gallons of solution. Either alone or in combination with 0.5 or 1.5 gallons of Marcol GX or Solvaspray 100 slight injury was noted. Slight injury is interpreted to mean approximately 5 per cent loss of a mature crop. This amount of injury is not considered serious enough to condemn the use of DDT emulsions on mature plants. More information is needed before DDT emulsions can be recommended for use on tomato plants. The plants grown in greenhouses may be expected to be more tender and susceptible to injury than mature field plants. The addition of the white oil caused no measurable increase in the injury to the plants. In addition to the DDT injury a few tests with methoxychlor and DDD emulsions resulted in very slight injury. No test with 72 per cent toxaphene emulsion at 4 or 2 quarts per 100 gallons, with or without added oil, resulted in injury. Neither Dilan at 6 quarts of 25 per cent emulsifiable concentrate or chlordane at 2 quarts of 72 emulsifiable concentrate resulted in injury. As wettable powders DDT, DDD, Dilan and dieldrin were tested at the rate of 1½ pounds of technical material with no injury resulting either with or without added Marcol GX or Volck paste. The Marcol GX and Volck paste were used at the rate of 0.3 gallons to 1.2 gallons per 100 gallons of solution. Wettable toxaphene at 3 pounds per 100 gallons, either with or without oil or Volck paste, resulted in no injury to the plants.

*Summary.*—DDT, DDD, Dilan and dieldrin gave good control of the tomato fruitworm, *Heliothis armigera* (Hbn.). Toxaphene gave good control at times, but at other times it was only fair. Methoxychlor, aldrin, and parathion generally gave poor control in these tests.

Dusts and sprays gave equally good control if the proper amounts were applied. When used as a spray, the DDT should be applied at the rate of 1½ pounds actual per acre, while as a dust an equivalent control can be obtained with 2½ pounds actual per acre. Differences in control obtained with wettable powders or emulsions were not significant.

The addition of sticking agents to the insecticide formulations increased the control about 80 per cent, but the excellent control obtained without their use would not justify recommending their use in a commercial control program.

Seasonal differences in the infestation of tomatoes affects the control obtained. As the season progresses the actual effectiveness of the control program decreases slightly. This occurs regardless of whether the untreated earworm population is decreasing or increasing.

No insecticide tested as a wettable powder or as an emulsion in these experiments caused injury to tomato plants under field conditions. A few cases of slight injury resulted from the combination of insecticides and an oil-type sticking agent, but even this amount of injury did not materially effect the yield. In laboratory tests some cases of injury resulted from applying emulsions or combinations of emulsions with sticking agents, but the injury was generally slight. Greenhouse tomato plants may be expected to be tender and thus more susceptible to injury than mature field-grown plants.

## American Mosquito Control Association

The 12th annual meeting of the American Mosquito Control Association, Inc., is to be held in the Edson Hotel, Beaumont, Texas, February 5–8, 1956. A practical application of mosquito control methods and equipment is being stressed in the program planning.

Plan now to attend!

# Sperm Distribution in the Spermathecae of Multiple-Mated Queen Honey Bees[1]

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Data on worker-progeny classifications from 35 multiple-mated queen honey bees, *Apis mellifera* L., were collected to determine whether a random sample of progeny can be used to form an unbiased estimate of the relative frequency, or distribution, of various sperm types within the spermathecae. Queens normally mate within 5 to 8 days after emerging from their cells and with from 6 to 7 drones (Taber 1954). If queens are mated by artificial insemination, about the same number of drones must be used to insure filling the spermatheca with a full supply of sperm (Mackensen & Roberts 1948). In either natural or artificial insemination the sperms migrate from the oviducts to the spermatheca of the queen and remain there until used for fertilization of her eggs.

METHOD.—Queens bearing a gene for an easily recognizable mutation in chitin color (cordovan, discovered by W. J. Nolan at the Agricultural Research Center) were used throughout these experiments. The presence of this gene leads to the following results: a mating between a virgin mutant queen and a nonmutant, or normal, drone gives only normal worker offspring; a mating between a virgin mutant queen and a mutant drone gives only mutant worker offspring; and a mating of a virgin mutant queen to both a normal and a mutant drone gives both types of worker progeny.

Samples of progeny were obtained from each of the queens, either daily or weekly, for various periods during her life, by two slightly different methods. One method consisted in caging the queen on a single comb for 24 hours and then giving this comb of eggs to ample nurse bees in the upper hive body of a queenright colony, separated from the queen by a queen excluder. On the 18th day the comb was removed to an incubator, where it was left until the 23rd day, at which time all worker bees had emerged and were killed and separated into the two color classes, normal and mutant, that existed among them as a result of the matings of their parent queen. Some bees emerged as early as the 19th day and some as late as the 23rd day, but most of them emerged on the 20th and 21st days. No difference was noted in rate of emergence of normal or mutant bees. Most of the samples taken by this method contained 500 to 1,000 bees. The other method was adopted to obtain smaller samples. It consisted in caging a comb of emerging brood in a incubator until sufficient bees had emerged and then killing and separating them into the two classes. The samples in this case ranged from 100 to 500 bees.

TYPES OF MATING.—Twelve queens, each of which had mated naturally with an unknown number of drones but at least one normal and one mutant drone formed the "A" group. Ten queens, the "M" group, were inseminated artificially with a mixture of sperm from normal and mutant drones, the sperm being mixed either on the finger or inside the syringe before insemination. Seven queens, the "N" group, were inseminated with sperm from normal drones and 2 days later with sperm from mutant drones. Six queens, the "C" group, were inseminated with sperm from mutant drones and 2 days later with sperm from normal drones. Approximately equal quantities of the two types of sperm were given each artificially inseminated queen.

METHOD OF ANALYSIS.—Chi-square tests for homogeneity of a binomial series given below were used to measure the probability that the samples collected came from a population with a common proportion of normal bees. The two formulas are as follows:

For an individual single sample (Anderson & Bancroft 1952)

$$\chi^2 = \frac{(N\bar{p} - x)^2}{N\bar{p}\bar{q}}$$

For a series of samples, or for all samples from one queen (Snedecor 1946)

$$\chi^2 = \frac{\Sigma px - \bar{p}\Sigma x}{\bar{p}\bar{q}}$$

Where $x$=number of normal bees in the sample, $N$=number of bees in the sample, $p=x/N$, $\bar{p}$=relative frequency of all normal bees, and $\bar{q}$=relative frequency of all mutant bees.

DATA.—Under the assumption that sperm comes at random to the oviduct, a graph of daily samples from three inseminated queens best shows the range and biased nature of the variation obtained. Further weekly counts were made on queens C-5 and N-17 still alive in 1952. These queens show less variation but, as indicated in table 1, variation is still much greater than could be expected from a normally distributed population.

All queens reported in table 1 show highly significant (beyond the 1% level of probability) values except two—A-4, significant at the 5% level, and C-4, which died after only seven samples could be collected and the value was not significant. Queens N-2 and M-8 show values not significant during the second year. There seems to be a tendency for the chi-square values to decrease during second- and third-year progeny counts, but five of the queens inseminated with mixed sperm reverse this trend.

Individual chi-square values were calculated on four queens—A-11, C-1, N-2, and N-3 (Table 2). The 1953 counts of N-2 are interesting in that only one value is highly significant while in 1952 nine are highly significant. The object of these calculations was to show statistically what is shown graphically in figure 1—that groups of samples occurring together are significantly different from the mean of all samples.

DISCUSSION.—Though much of the material is highly condensed (complete data are presented on only four representative queens) several points definitely come to light with these data.

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[2] In cooperation with Louisiana State University.

**Table 1.—Summary and chi-square analyses of progeny counts from 35 multiple-mated queens.**

| Queen | Year | Number of Samples | Per Cent of Normal Progeny | Total Bees | Chi-square | Degrees of Freedom |
|---|---|---|---|---|---|---|
| A-1 | 1952 | 18 | 86.80 | 6,667 | 89.25 | 17 |
| A-2 | 1952 | 20 | 59.84 | 9,236 | 382.07 | 19 |
| | 1953 | 23 | 67.09 | 6,128 | 150.42 | 22 |
| | 1954 | 9 | 72.68 | 2,688 | 16.564 | 8[a] |
| | | 52 | 64.21 | 18,052 | 741.33 | 51 |
| A-3 | 1952 | 9 | 59.19 | 4,161 | 133.77 | 8 |
| A-4 | 1952 | 10 | 80.68 | 4,109 | 17.446 | 9[a] |
| A-5 | 1952 | 19 | 97.09 | 7,729 | 82.01 | 18 |
| A-6 | 1952 | 21 | 95.48 | 10,092 | 270.09 | 20 |
| A-7 | 1952 | 21 | 75.29 | 7,951 | 260.04 | 20 |
| A-8 | 1952 | 22 | 75.62 | 7,923 | 41.632 | 21 |
| A-9 | 1952 | 20 | 76.12 | 9,924 | 361.9 | 19 |
| A-10 | 1952 | 20 | 65.30 | 7,764 | 143.7 | 19 |
| A-11 | 1952 | 30 | 79.65 | 10,324 | 741.1 | 29 |
| | 1953 | 7 | 69.65 | 1,789 | 18.851 | 6 |
| | | 37 | 78.17 | 12,113 | 816.8 | 36 |
| A-12 | 1952 | 22 | 89.24 | 9,581 | 98.91 | 21 |
| | 1953 | 20 | 90.51 | 7,122 | 22.245 | 19 |
| | | 42 | 89.78 | 16,703 | 131.47 | 41 |
| C-1 | 1952 | 32 | 75.10 | 19,026 | 902.02 | 31 |
| | 1953 | 23 | 67.92 | 7,986 | 64.49 | 22 |
| | 1954 | 10 | 63.15 | 3,425 | 23.816 | 9 |
| | | 65 | 71.87 | 30,437 | 1,220.1 | 64 |
| C-2 | 1952 | 32 | 56.65 | 19,252 | 614.10 | 31 |
| | 1953 | 15 | 46.66 | 5,564 | 47.29 | 14 |
| | | 47 | 54.40 | 24,816 | 829.207 | 46 |
| C-3 | 1952 | 22 | 52.68 | 12,651 | 757.76 | 21 |
| | 1953 | 11 | 61.72 | 4,125 | 47.63 | 10 |
| | | 33 | 54.90 | 16,776 | 911.15 | 32 |
| C-4 | 1952 | 7 | 34.07 | 2,747 | 10.9150 | 6[b] |
| C-5 | 1951 | 50 | 29.29 | 25,300 | 3,725 | 49 |
| | 1952 | 27 | 46.46 | 17,731 | 739.1 | 26 |
| | | 77 | 36.36 | 43,031 | 5,456 | 76 |
| C-8 | 1951 | 51 | 35.58 | 26,826 | 4,084 | 50 |
| M-1 | 1953 | 11 | 37.69 | 2,531 | 49.44 | 10 |
| | 1954 | 11 | 50.88 | 4,489 | 91.80 | 10 |
| | | 22 | 46.13 | 7,020 | 256.38 | 21 |
| M-2 | 1953 | 12 | 65.83 | 4,911 | 72.68 | 11 |
| | 1954 | 10 | 53.21 | 4,623 | 68.37 | 9 |
| | | 22 | 59.71 | 9,534 | 296.38 | 21 |
| M-3 | 1953 | 12 | 59.66 | 3,699 | 233.06 | 11 |
| | 1954 | 10 | 53.09 | 3,820 | 57.31 | 9 |
| | | 22 | 56.32 | 7,519 | 319.08 | 21 |
| M-5 | 1953 | 11 | 45.11 | 2,891 | 63.88 | 10 |
| | 1954 | 10 | 45.76 | 4,904 | 368.76 | 9 |
| | | 21 | 45.52 | 7,795 | 433.13 | 20 |
| M-7 | 1953 | 12 | 32.53 | 4,015 | 99.20 | 11 |
| | 1954 | 10 | 40.10 | 4,998 | 259.12 | 9 |
| | | 22 | 36.72 | 9,013 | 416.41 | 21 |
| M-8 | 1953 | 12 | 38.96 | 3,627 | 78.98 | 11 |
| | 1954 | 10 | 43.16 | 3,448 | 4.6186 | 9[b] |
| | | 22 | 41.00 | 7,075 | 95.22 | 21 |
| M-9 | 1953 | 12 | 48.66 | 2,982 | 67.84 | 11 |
| M-10 | 1953 | 12 | 42.37 | 3,080 | 40.46 | 11 |
| | 1954 | 10 | 38.23 | 3,960 | 194.80 | 9 |
| | | 22 | 40.04 | 7,040 | 245.11 | 21 |
| M-12 | 1953 | 12 | 50.48 | 3,211 | 25.67 | 11 |
| | 1954 | 10 | 51.17 | 4,671 | 40.78 | 9 |
| | | 22 | 50.88 | 7,882 | 66.825 | 21 |
| M-13 | 1953 | 12 | 53.31 | 3,812 | 113.30 | 11 |
| | 1954 | 10 | 59.76 | 3,805 | 84.31 | 9 |
| | | 22 | 56.53 | 7,617 | 229.57 | 21 |
| N-1 | 1952 | 14 | 51.27 | 7,484 | 122.24 | 13 |
| N-2 | 1952 | 30 | 62.72 | 10,591 | 478.05 | 29 |
| | 1953 | 23 | 63.78 | 5,055 | 29.743 | 22[b] |
| | | 53 | 63.06 | 15,646 | 511.01 | 52 |
| N-3 | 1952 | 25 | 68.52 | 12,977 | 534.46 | 24 |
| | 1953 | 22 | 59.61 | 6,853 | 389.28 | 21 |
| | | 47 | 65.44 | 19,830 | 1,082.2 | 46 |
| N-4 | 1952 | 20 | 73.66 | 12,682 | 626.1 | 19 |
| | 1953 | 23 | 68.03 | 7,398 | 119.01 | 22 |
| | 1954 | 10 | 59.09 | 2,713 | 63.26 | 9 |
| | | 53 | 70.10 | 22,793 | 1,024.6 | 52 |
| N-5 | 1952 | 21 | 71.79 | 13,230 | 872.4 | 20 |
| N-6 | 1952 | 21 | 72.29 | 9,295 | 1,189.7 | 20 |
| | 1953 | 23 | 70.90 | 5,914 | 628.6 | 22 |
| | | 44 | 71.75 | 15,209 | 1,819.1 | 43 |
| N-17 | 1951 | 60 | 31.73 | 35,027 | 2,205 | 59 |
| | 1952 | 17 | 56.38 | 12,817 | 732 | 16 |
| | | 77 | 38.34 | 47,844 | 5,194 | 76 |

[a] Five per cent.
[b] Not significant.

**Table 2.—Complete data and individual chi-square analyses for four representative multiple-mated queens.**

| Date | Per Cent of Normal Progeny | Total Bees | Chi-square |
|---|---|---|---|
| | Queen A-11, Mated naturally | | |
| *1952* | | | |
| May 14 | 67.82 | 174 | 10.91 |
| 21 | 73.56 | 174 | 2.16 |
| 28 | 74.94 | 427 | 2.61 |
| June 5 | 78.64 | 295 | — |
| 11 | 82.62 | 328 | 3.81 |
| 18 | 88.25 | 349 | 20.81 |
| 25 | 74.93 | 359 | 2.20 |
| July 2 | 64.26 | 305 | 34.55 |
| 9 | 74.84 | 318 | 2.07 |
| 16 | 81.73 | 416 | 3.09 |
| 23 | 86.74 | 377 | 16.22 |
| 30 | 93.46 | 382 | 52.33 |
| Aug. 5 | 90.97 | 443 | 42.53 |
| 11 | 90.79 | 467 | 43.54 |
| 18 | 89.64 | 483 | 37.24 |
| 25 | 91.53 | 496 | 51.94 |
| Sept. 1 | 92.68 | 355 | 43.79 |
| 8 | 87.79 | 475 | 25.77 |
| 15 | 83.73 | 424 | 7.63 |
| 22 | 82.39 | 352 | 3.65 |
| 29 | 81.33 | 332 | 1.95 |
| Oct. 6 | 80.21 | 503 | 1.12 |
| 13 | 74.05 | 370 | 3.66 |
| 20 | 72.85 | 361 | 5.98 |
| 29 | 55.67 | 379 | 112.51 |
| Nov. 3 | 60.79 | 329 | 58.28 |
| 12 | 60.15 | 261 | 49.60 |
| 24 | 67.20 | 125 | 8.80 |
| Dec. 3 | 54.79 | 146 | 46.68 |
| 12 | 60.50 | 119 | 21.71 |
| *1953* | | | |
| Mar. 17 | 78.91 | 256 | — |
| 24 | 71.53 | 144 | 3.75 |
| 30 | 77.27 | 110 | — |
| Apr. 6 | 66.75 | 421 | 32.21 |
| 13 | 65.44 | 217 | 20.57 |
| 20 | 66.55 | 296 | 23.43 |
| 27 | 68.41 | 345 | 19.29 |
| Average or total | 78.17 | 12,113 | 816.39 |

Table 2.—continued

| Date | Per Cent of Normal Progeny | Total Bees | Chi-square |
|---|---|---|---|
| Queen C-1, Inseminated in 1952 | | | |
| *1952* | | | |
| Apr. 11 | 63.24 | 487 | 17.83 |
| 20 | 60.94 | 576 | 33.98 |
| 28 | 63.05 | 609 | 23.34 |
| May 4 | 79.69 | 778 | 23.58 |
| 11 | 63.13 | 849 | 31.99 |
| 18 | 65.88 | 381 | 6.69 |
| 25 | 66.80 | 756 | 9.60 |
| June 1 | 66.58 | 749 | 10.67 |
| 8 | 68.31 | 833 | 5.20 |
| 15 | 69.98 | 906 | 1.60 |
| 23 | 65.59 | 494 | 9.62 |
| 29 | 72.59 | 529 | .14 |
| July 6 | 65.38 | 800 | 16.66 |
| 13 | 73.60 | 769 | 1.16 |
| 20 | 93.00 | 557 | 123.24 |
| 27 | 91.17 | 589 | 108.76 |
| Aug. 2 | 90.38 | 520 | 88.40 |
| 8 | 81.31 | 503 | 22.28 |
| 15 | 89.75 | 566 | 89.68 |
| 22 | 85.80 | 796 | 76.57 |
| 29 | 83.65 | 948 | 65.11 |
| Sept. 5 | 84.76 | 807 | 66.43 |
| 12 | 82.21 | 1,175 | 62.25 |
| 18 | 79.58 | 867 | 25.61 |
| 25 | 76.71 | 438 | 5.12 |
| Oct. 20[a] | 76.72 | 262 | 3.09 |
| 29 | 69.07 | 375 | 1.43 |
| Nov. 3 | 72.09 | 258 | .01 |
| 12 | 70.65 | 293 | .21 |
| 24 | 67.20 | 125 | 1.29 |
| Dec. 3 | 71.12 | 187 | .04 |
| 12 | 70.49 | 244 | .22 |
| *1953* | | | |
| Mar. 23 | 76.24 | 202 | 1.94 |
| 30 | 65.38 | 676 | 14.04 |
| Apr. 7 | 60.28 | 282 | 18.64 |
| 13 | 61.73 | 243 | 12.32 |
| 20 | 61.49 | 309 | 16.39 |
| 27 | 67.06 | 513 | 5.84 |
| May 5 | 66.37 | 684 | 10.17 |
| 11 | 70.61 | 313 | .24 |
| 18 | 69.14 | 256 | .95 |
| 25 | 75.74 | 272 | 2.01 |
| June 1 | 68.16 | 267 | 1.82 |
| 8 | 69.38 | 320 | .99 |
| 15 | 61.77 | 327 | 16.48 |
| 22 | 73.80 | 271 | .49 |
| 29 | 71.28 | 188 | .03 |
| July 6 | 71.17 | 333 | .08 |
| 13 | 69.26 | 478 | 1.64 |
| 20 | 63.24 | 370 | 13.61 |
| 27 | 66.67 | 300 | 4.01 |
| Aug. 3 | 72.67 | 161 | .05 |
| 10 | 74.77 | 325 | 1.35 |
| 17 | 70.47 | 569 | .56 |
| 24 | 65.14 | 327 | 7.32 |
| *1954* | | | |
| Mar. 29 | 70.10 | 311 | .48 |
| Apr. 12 | 69.53 | 384 | 1.04 |
| 19 | 64.71 | 255 | 6.43 |
| 26 | 59.55 | 445 | 3.33 |
| May 3 | 62.39 | 335 | 14.84 |
| 10 | 60.75 | 507 | 30.93 |
| 17 | 61.32 | 287 | 15.72 |
| 24 | 59.25 | 454 | 35.65 |
| 31 | 68.59 | 191 | 1.00 |
| June 8 | 60.55 | 256 | 16.14 |
| Average or total | 71.87 | 30,437 | 1,188.33 |

Table 2.—continued

| Date | Per Cent of Normal Progeny | Total Bees | Chi-square |
|---|---|---|---|
| Queen N-2, Inseminated 1952 | | | |
| *1952* | | | |
| Apr. 24 | 67.13 | 286 | 2.02 |
| May 1 | 70.46 | 413 | 9.67 |
| 8 | 87.74 | 620 | 162.09 |
| 15 | 70.91 | 471 | 12.48 |
| 22 | 63.18 | 584 | .00 |
| 29 | 63.71 | 259 | .05 |
| June 5 | 64.30 | 451 | .30 |
| 12 | 66.60 | 494 | 2.66 |
| 19 | 61.62 | 469 | .42 |
| 26 | 63.78 | 370 | .09 |
| July 3 | 61.10 | 473 | .79 |
| 10 | 59.09 | 308 | 2.08 |
| 17 | 45.55 | 472 | 62.21 |
| 24 | 43.44 | 320 | 52.91 |
| 31 | 47.81 | 433 | 43.32 |
| Aug. 6 | 49.10 | 391 | 32.73 |
| 13 | 52.71 | 425 | 19.56 |
| 20 | 44.84 | 339 | 48.37 |
| 27 | 61.71 | 457 | .36 |
| Sept. 3 | 68.20 | 522 | 5.91 |
| 10 | 66.07 | 619 | 2.40 |
| 18 | 67.00 | 297 | 1.98 |
| 25 | 64.38 | 146 | .11 |
| Oct. 3 | 58.59 | 99 | .84 |
| Oct. 27[a] | 70.51 | 234 | 5.55 |
| Nov. 3 | 67.31 | 52 | .40 |
| 12 | 71.08 | 204 | 5.59 |
| 24 | 66.67 | 153 | .85 |
| Dec. 3 | 72.18 | 133 | 4.73 |
| 12 | 64.95 | 97 | .14 |
| *1953* | | | |
| Mar. 17 | 68.00 | 175 | 1.82 |
| 24 | 64.02 | 164 | .07 |
| 30 | 61.02 | 118 | .21 |
| Apr. 7 | 64.67 | 184 | .21 |
| 13 | 58.08 | 229 | 2.44 |
| 20 | 67.14 | 426 | 3.02 |
| 27 | 63.48 | 230 | .02 |
| May 5 | 64.56 | 206 | .20 |
| 11 | 62.14 | 243 | .09 |
| 18 | 64.97 | 157 | .25 |
| 25 | 59.39 | 293 | 1.71 |
| June 1 | 58.45 | 219 | 2.00 |
| 8 | 73.29 | 161 | 7.26 |
| 15 | 65.65 | 524 | 1.49 |
| 22 | 66.90 | 145 | .93 |
| 29 | 60.87 | 184 | .37 |
| July 6 | 57.39 | 176 | 2.44 |
| 20 | 78.18 | 55 | 5.38 |
| 27 | 64.12 | 262 | .13 |
| Aug. 3 | 64.22 | 232 | .14 |
| 10 | 60.74 | 135 | .31 |
| 17 | 63.81 | 257 | .06 |
| 24 | 63.57 | 280 | .03 |
| Average or total | 63.03 | 15,646 | 511.133 |
| Queen N-3, Inseminated in 1952 | | | |
| *1952* | | | |
| Apr. 29 | 55.56 | 144 | 6.22 |
| May 7 | 55.29 | 662 | 30.17 |
| 14 | 54.25 | 518 | 28.70 |
| 21 | 62.25 | 408 | 1.83 |
| 28 | 66.13 | 437 | .09 |

[a] Previous samples dated day comb was given to queen; this sample and all succeeding ones on day of emerging brood, approximately 20 days difference.

Table 2.—continued

| DATE | PER CENT OF NORMAL PROGENY | TOTAL BEES | CHI-SQUARE |
|---|---|---|---|
| June 4 | 61.98 | 747 | 3.96 |
| 11 | 63.99 | 511 | .47 |
| 18 | 65.85 | 533 | .04 |
| 25 | 67.14 | 630 | .81 |
| July 2 | 60.61 | 358 | 3.69 |
| 9 | 66.03 | 627 | .10 |
| 16 | 63.19 | 432 | .96 |
| 23 | 68.00 | 400 | 1.16 |
| 30 | 65.75 | 619 | .03 |
| Aug. 8 | 65.77 | 222 | .01 |
| 13 | 69.25 | 670 | 4.31 |
| 20 | 70.31 | 512 | 5.38 |
| 27 | 83.27 | 801 | 112.62 |
| Sept. 3 | 81.47 | 750 | 85.18 |
| 11 | 80.58 | 824 | 83.54 |
| 18 | 83.90 | 671 | 101.16 |
| Oct. 13[a] | 86.48 | 392 | 76.74 |
| 20 | 62.32 | 207 | .89 |
| 27 | 58.95 | 743 | 13.84 |
| Nov. 3 | 59.12 | 159 | 2.81 |
| *1953* | | | |
| Mar. 23 | 49.75 | 203 | 22.08 |
| 30 | 72.10 | 233 | 4.57 |
| Apr. 6 | 64.75 | 295 | .06 |
| 13 | 52.44 | 307 | 22.93 |
| 20 | 60.70 | 486 | 4.82 |
| 27 | 60.74 | 540 | 5.28 |
| May 5 | 54.60 | 511 | 26.56 |
| 11 | 58.06 | 403 | 9.69 |
| 18 | 57.52 | 339 | 9.40 |
| 25 | 49.32 | 365 | 41.97 |
| June 1 | 55.59 | 295 | 12.65 |
| 8 | 58.24 | 182 | 4.17 |
| 15 | 46.81 | 376 | 57.70 |
| 22 | 41.86 | 215 | 52.87 |
| 29 | 42.05 | 195 | 47.17 |
| July 6 | 46.25 | 160 | 26.04 |
| 13 | 53.80 | 158 | 9.48 |
| 20 | 47.34 | 188 | 27.24 |
| 27 | 66.27 | 249 | .08 |
| Aug. 3 | 87.45 | 231 | 49.46 |
| 10 | 85.54 | 408 | 72.87 |
| 17 | 72.18 | 514 | 10.32 |
| Average or total | 65.44 | 19,830 | 1,082.09 |

Sperm from multiple matings does not mix appreciably inside the spermatheca during mating or after, nor could it be mixed by methods used before insemination. No mixing whatsoever would have given a few samples of 100% normal bees and a few of 100% cordovan bees. This was never obtained, and the mechanism that prevents the attainment of 100% normal or cordovan bees is not evident in the data. It is possible that sperms clump or stick together either as large or small clumps and may after a year or more become more mixed or random through some movement inside the spermatheca. This could effect

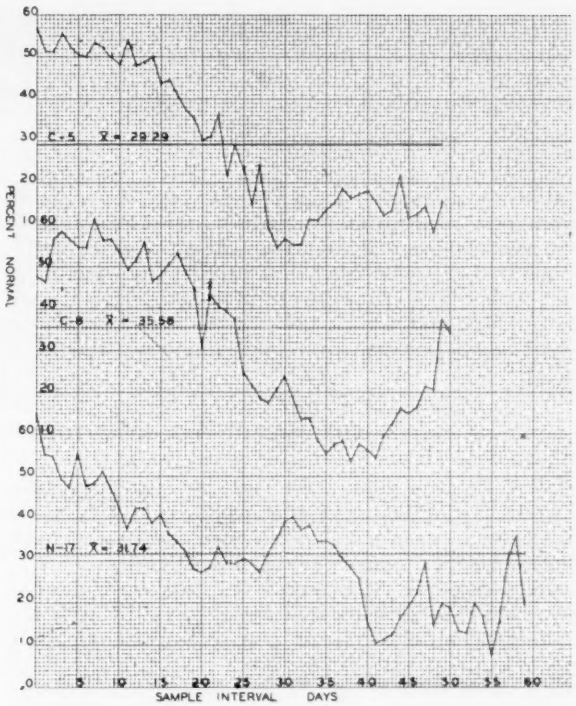


FIG. 1.—Per cent of normal progeny from three inseminated queens in samples collected daily in 1951.

daughter queens raised from naturally mated breeding stock, because any single sample, or group of samples collected during a short period of time, would not be an unbiased estimate of the sperm distribution in the spermathecae of a multiple-mated queen. It is conceivable that when a breeding queen mates with five genetically desirable drones and one less desirable drone large numbers of daughter queens could be raised from eggs fertilized with sperm from the one undesirable drone.

CONCLUSION.—Sperm from multiple matings does not mix appreciable inside the spermatheca, during or after mating, nor can it be mixed by methods used before insemination. Many random samples drawn from 35 queens multiple-mated naturally or artificially showed that a bias exists in such samples.

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# Mating Habits of the Tobacco Hornworm[1]

NORMAN ALLEN, *Entomology Research Branch, Agr. Res. Serv., U.S.D.A.*, and C. R. HODGE, *South Carolina Agricultural Experiment Station.*

Only about one-fourth of the moths of the tobacco hornworm, *Protoparce sexta* (Johan.), caught in black-light traps are females, according to Stahl's (1954) and our observations. Since Madden & Chamberlin (1945) found that the sexes occur in approximately equal numbers in the field, it is evident that the light traps catch only a small part of the adult female population of the most important hornworm attacking tobacco in the South.

The possiblity that the capture of such a high percentage of male moths in the traps might cause a large number of females to remain unfertilized raised the question as to whether the male would mate with more than one female. To obtain information on this and other mating habits of tobacco hornworm moths, biological studies were made at Florence, S. C., during the summer of 1954.

EXPERIMENTAL PROCEDURE.—Madden and Chamberlin found that cloth-covered cages 14 by 14 by 9 feet were satisfactory for mating studies, but that the moths would mate through the cage walls. Therefore, cages with inside measurements of 14 by 14 by 9 feet and outside measurements of 16 by 16 by 10 feet were used in the current investigations. The cages were covered with shade-tobacco cloth (Fig. 1). Only two cages were used. Twenty-one tobacco plants were transplanted in each cage on June 9. They were spaced so that there were three rows of plants with seven plants per row in each cage. The plants were watered from time to time, and even with a dry season prevailing they had grown to the top of the cage and several plants in each cage were flowering when the mating studies were begun. The cages were supplied with glass vials that contained either jimsonweed or tobacco blooms and a sugar solution for food. However, the moths seemed to prefer the tobacco blooms on the growing plants.

To be certain that an accurate record of all matings was obtained, it was necessary to obtain larvae and rear all the females and most of the males that were used. The full-grown hornworm larvae were collected from the field and allowed to pupate in the soil. For this purpose cylindrical screen cages were placed about 6 inches apart on the ground, and the cages and the intervening spaces were filled with pulverized soil which was allowed to become firm before any larvae were installed (Fig. 2). At the outset one larva was placed in each cage, but later two larvae were used. Each cage was covered with a cloth sheeting held in placed by a rubber band. The larvae were fed tobacco suckers until they entered the soil to pupate. After they had pupated the cloth tops were replaced with wire screen.

After the pupae had remained in the soil for about 2 weeks, adult moths began to emerge. Therefore, the pupae were removed from the soil and placed in screen emergence cages; however, only a small percentage of them emerged as adults. Better results would probably have been obtained if they had been left in the soil until they emerged as adults.

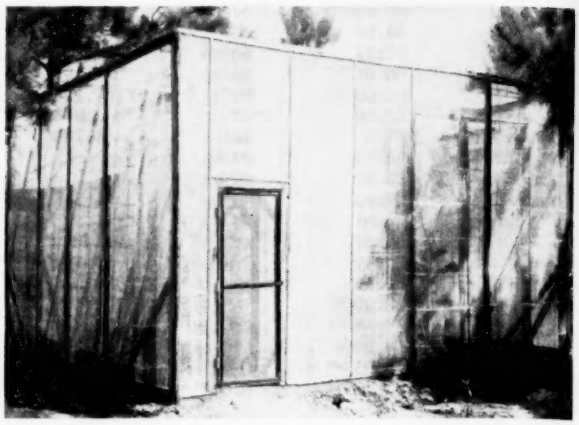

FIG. 1.—Double-walled cloth-covered cage used in tobacco hornworm mating studies.

The male and female pupae were separated before they were placed in the emergence cages. The characters for sex differentiation in the pupae are located on the two posterior segments of the abdomen (Fig. 3). The determination of the female pupae is fairly simple and can be positively made; however, the genitalia of some male pupae are less pronounced than those of others.

The male and female moths were kept in separate cages except when used in the mating studies. A known number of newly emerged males and females were then placed in the same cage. This work was begun just before dusk, and observations were continued until all matings had ceased for the night. While a pair of moths were mating, both sexes were marked on one wing with a thin line of fast-drying automobile lacquer. Only one color was used during a given night, except where males were collected from the outside and introduced into a cage. Where a male mated with more than one female, his wings would show a different color for each mating. The time when mating began and ended was carefully noted for each pair of moths. When the observations for a given night had been completed, the males were transferred to the other mating cage.

The adult moths emerged at a time when there were moonlight nights. This was fortunate since it was possible to observe most of the moths' activities during the mating studies without the aid of artificial light. An ordinary flashlight was the only artificial light used.

TIME WHEN MATING OCCURRED.—The time when mating began for the 20 pairs for which records were obtained was as follows:

| | |
|---|---|
| 9 to 10 p. m. | 3 |
| 10 to 11 p. m. | 1 |
| 11 to 12 midnight | 3 |
| 12 midnight to 1 a. m. | 9 |
| 1 to 2 a. m. | 4 |

[1] Accepted for publication March 4, 1955.

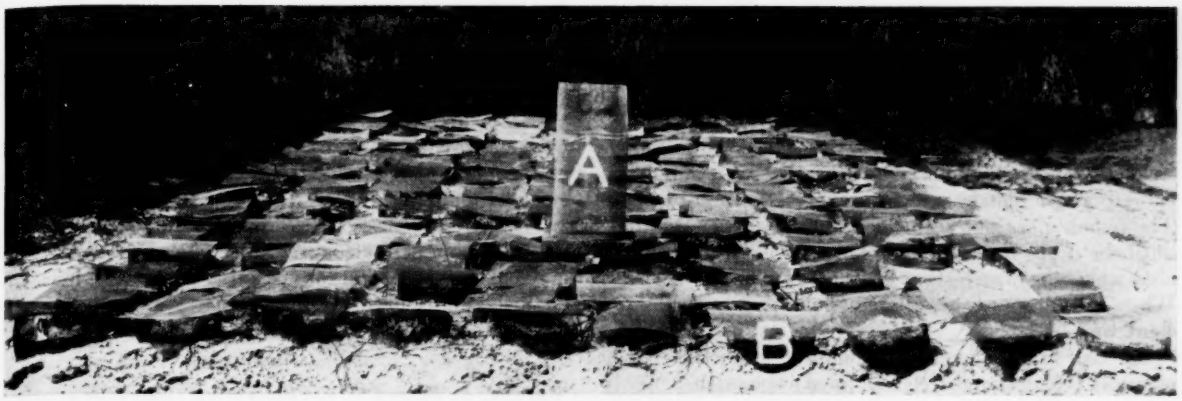


FIG. 2.—Cages in which hornworm larvae pupated. *A*, type of screen cage used; *B*, cage in position in the soil.

On August 14 several virgin females were caged with a number of virgin males. Only three pairs began mating before midnight, and there was no evidence of any mating interest on the part of the other moths in the cage. At 12:40 a. m. two males that were outside the mating cage were collected with an insect net, marked, and released in the cage. At 12:49 there was no additional mating activity but at 1 a. m. nine pairs were mating, including the two males that had been collected on the outside. A similar phenomenon was observed on two other nights, although there were fewer moths in the cage at the time. From these and other observations the authors believe that more matings occur after midnight than before, and that for some unknown reason the urge to mate occurs in a number of individuals at about the same time.

LENGTH OF MATING PERIOD.—Mating of the 20 pairs observed ranged from 1 hour and 13 minutes to 5 hours and 45 minutes, with an average of 2 hours and 49 minutes. When the union had been completed, the pair were facing in opposite directions, the female above and the male below. Unless disturbed, the moths remained quiet and in this position until a few minutes before they ceased mating. Then the female began to move her abdomen, apparently to free herself from the male. After mating the male sought food, whereas the female remained quiescent for some time before she attempted to feed. The length of the mating period appeared to be governed by the time that it began, since there was a tendency for the moths to continue mating until just before dawn.

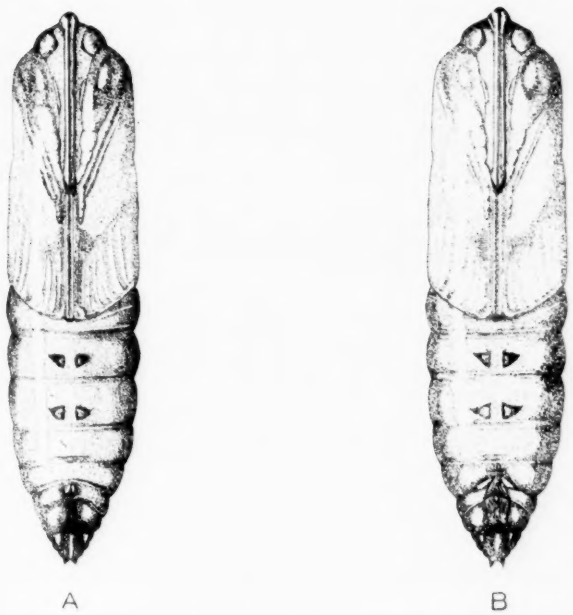


FIG. 3.—Tobacco hornworm pupae. A, male; B, female. Enlarged.

NUMBERS OF TIMES MOTHS MATED.—Only virgin females were observed to mate, although both newly emerged and older males were caged with females that had already mated. On the other hand, of 11 males for which mating records were obtained 6 mated with more than 1 female and 3 mated with 3 females. Some males mated with 2 and 1 male with 3 females on consecutive nights. Only 1 male was observed to mate with 2 females in one night, and this was where a mating pair was accidentally separated. The female that had been separated never did mate with another male, but the male began mating with another female in 1 hour and 20 minutes. It is doubtful whether a male mates with more than one female in one night under natural conditions.

DISCUSSION.—Several investigators who have trapped hornworm moths have noted that a virgin female is more attractive to males than any type of light or bait trap thus far developed. This attractiveness was evidenced when Madden and Chamberlin noted that the moths would mate through the walls of cloth-covered cages. Additional evidence was obtained in the following observations.

The mating cages were located in a wooded area some distance from the nearest tobacco field. Despite this fact, males of the tobacco hornworm visited the cages every night that observations were continued throughout the night. On three nights visiting males were collected, marked, and released in the cages. Of 6 males used in this manner, 4 mated with virgin females that were in the cage. If only one virgin female was in the cage, the males on the outside would fly to a point opposite her. If

several virgin females were in the cage, the males would fly all around the cage and were harder to capture. All the visiting males were noted after midnight. When a male was captured and released in a cage, he first tried to escape, but after a few minutes he sought the female and mated immediately.

It was repeatedly noted, however, that males might be close to virgin females and yet pay no attention to them. The female does not seem to be attractive to the male until she drops her abdomen. This was especially noticeable when she was resting on the top wall of the cage. When she dropped her abdomen mating ensued in a short time.

On the first night of the mating studies 4 newly emerged females were released in a cage with 3 newly emerged males and 5 males that had been caught on the same night in light traps. Although there was food in the cage a male and female that had emerged the previous night mated before they fed.

Although all the females and most of the males used in these studies were newly emerged adults, a few did not mate while they were under observation. Some of those that failed to mate on the first night mated on subsequent nights. Where males that had mated on previous nights were caged with newly emerged males and females, some of the older males mated a second time before newly emerged males did.

The attractiveness of the virgin female to the male and the fact that one male will fertilize more than one female make it unlikely that any healthy females remain unfertilized under natural conditions.

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# Poison Bait for the Control of House Flies on Military Reservations[1]

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Fly control on military installations is accomplished primarily by sanitation, but chemical control is frequently used in and about mess halls or other places where flies are attracted or congregate. Chemical control includes DDT residual treatments of buildings, grounds, and garbage-disposal facilities and DDT-pyrethrum or DDT-allethrin space sprays in buildings.

Although reports of the failure of DDT and other chlorinated hydrocarbon insecticides to give satisfactory control of flies on military installations have been infrequent, Major Arthur Kidwell[2] found moderate to high resistance to DDT in 17 strains of house flies collected from military installations in the Second Army Area, and moderate resistance to lindane in some of the strains. These results indicate that an alternate method of fly control may be necessary should fly resistance to chlorinated insecticides increase.

Gahan *et al.* (1954) found sugar baits prepared with Diazinon, Bayer L 13/59, or malathion to be highly effective for the control of house flies in dairy barns. It was therefore thought that posison baits might be effective on military reservations, and tests were made at several locations during the summer of 1954.

MATERIALS AND METHODS.—Chlorthion at a concentration of 1 or 2 per cent was used as the toxicant in sugar baits, as this insecticide is among the least toxic to warm-blooded animals of the available organic phosphorus insecticides. The baits were prepared by mechanically mixing technical Chlorthion with granulated sugar.

Outside of buildings or tents the baits were sprinkled lightly around garbage racks, entrances, and other locations where flies tended to congregate; indoors they were sprinkled on the floors, window sills, stud girts, and other places where they could not contaminate food, utensils, or furniture. The degree of effectiveness of the treatments was based on the total count of flies before and 24 hours after treatment, and in one experiment counts were also made after 4 hours. Since mess sanitation was excellent, fly populations were low at all locations.

TESTS AT PINE CASTLE AIR FORCE BASE.—At the Pine Castle Air Force Base in Florida tests were conducted at a large consolidated mess hall with a floor area of 7,600 square feet (mess No. 1) and a smaller independent mess with 3,100 square feet (mess No. 2). Applications of 200 to 400 grams of sugar bait containing 2 per cent of Chlorthion were made 4 days each week unless populations were reduced to less than five flies per building in a shorter period. Approximately half the bait was used outside and half inside.

**Table 1.—Daily applications of 1 per cent Chlorthion bait against house flies at Mountain Camp, Dahlonega, Ga.**

| LOCATION | GRAMS OF BAIT PER TREATMENT | NUMBER OF FLIES BEFORE TREATMENT | HOURS AFTER MOST RECENT TREATMENT | PER CENT REDUCTION AFTER | |
|---|---|---|---|---|---|
| | | | | First Treatment | Second Treatment |
| Kitchen | 100 | 38 | 4 | 46 | 91 |
| | | | 24 | 91 | 97 |
| Latrine | 100 | 12 | 4 | 75 | 92 |
| | | | 24 | 75 | 100 |
| Garbage rack and mess-kit laundry | 100 | 66 | 4 | 58 | 97 |
| | | | 24 | 100 | 97 |
| Class and recreation tent | 200 | 62 | 4 | 76 | 100 |
| | | | 24 | 98 | 98 |

[1] Accepted for publication March 4, 1955. This work was conducted under funds allotted by the Department of the Army to the Entomology Research Branch.

[2] Unpublished report.

Table 2.—Sugar bait containing 1 per cent of Chlorthion against house flies in mess halls at Camp Stewart, Ga.[a]

| Mess No. | Per Cent Reduction After First Treatment | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | On Garbage Racks | | | | | | In Mess Halls | | | | | |
| | 1 Day | 3 Days | 4 Days | 5 Days | 6 Days | 7 Days | 1 Day | 3 Days | 4 Days | 5 Days | 6 Days | 7 Days |
| 1 | 95 | 90 | 80 | 97 | 97 | 94 | 46 | 32 | 40 | 38 | 76 | 89 |
| 2 | 88 | 93 | 76 | 98 | 92 | 98 | 57 | 88 | 87 | 97 | 97 | 97 |
| 3 | — | — | 100 | 95 | 100 | 95 | — | — | 95 | 95 | 95 | 93 |
| 4 | 96 | 94 | 93 | 93 | 98 | 93 | 76 | 81 | 96 | 96 | 96 | 92 |
| 5 | 98 | 91 | 98 | 100 | 98 | 98 | 54 | 41 | 78 | 96 | 100 | 96 |
| 6 | — | — | 97 | 97 | 100 | 97 | — | — | 98 | 100 | 98 | 98 |

[a] Two hundred grams applied daily except second day.

One application of 400 grams of bait in mess No. 1 reduced fly populations inside the building 48 per cent in 24 hours. Three additional applications gave excellent control, reaching 94 per cent on the fourth day. After 3 days without treatment fly populations increased to approximately one-half the original, and four more treatments of 400 grams were required to give excellent control. After 10 days without treatment fly populations recovered sufficiently for additional testing, and the mess was given a single treatment of 200 grams of bait. This treatment gave good control (84 per cent), and a similar single treatment in mess No. 2 gave excellent results (91 per cent).

TESTS AT A MOUNTAIN TRAINING CAMP.—In June 1954 tests were conducted at the Mountain Training Camp, Ranger Division, at Dahlonega, Ga., to evaluate 1 per cent Chlorthion sugar bait for the control of house flies at tent installations. At this camp screened squad tents with sawdust floors are utilized as quarters, orderly room, kitchen, dining tents, shower, and latrine, an unscreened hospital-ward tent serves for classes and recreation, and a large plank platform is used as a garbage rack and mess-kit washing area. Tests at this installation were conducted in the kitchen, class and recreation tent, latrine, and at the garbage rack and mess-kit washing area; in the dining tent fly populations were insufficient to warrant testing. Results of these tests are presented in table 1.

Fair control of flies was obtained 4 hours after the first treatment in all locations, and excellent control after 24 hours in all except the latrine. Control of flies was excellent both 4 and 24 hours after the second treatment, when tests were discontinued.

TESTS AT CAMP STEWART, GA.—Tests were conducted at Camp Stewart, Ga., to evaluate 1 per cent Chlorthion sugar bait for the control of house flies around typical army mess halls with a floor area of 2,000 square feet. Daily except Sunday 200 grams of bait was applied both inside and outside the messes. The results of these tests are presented in table 2.

One application to the garbage racks and exteriors of the messes generally gave excellent control of flies 1 day after the first treatment, and the same high degree of control was maintained throughout the test period. Immediate control inside the mess halls was somewhat lower, but excellent control was obtained in three messes with four applications and good control in one mess with six treatments. Excellent control was obtained in two messes with a single treatment just before the mess closed in the evening.

SUMMARY.—At the Air Force Base at Pine Castle, Fla., four daily applications of 400 grams of 2 per cent Chlorthion sugar bait gave excellent control of flies at mess No. 1. After 3 days a second series of four treatments gave similar results. Ten days later one treatment of 200 grams gave satisfactory control. At mess No. 2 a similar treatment gave excellent control.

At the Mountain Training Camp, Dahlonega, Ga., fair control of flies was obtained in the kitchen, class and recreation tent, garbage rack, and latrine 4 hours after the first treatment with 100 or 200 grams of 1 per cent Chlorthion sugar bait, and excellent control in all locations except the latrine after 24 hours. Control was excellent 4 and 24 hours after the second treatment.

At Camp Stewart, Ga., excellent control was obtained at garbage racks with one treatment of 200 grams of 1 per cent Chlorthion sugar bait. Excellent control was also obtained inside three mess halls with four similar treatments, and good control in one mess with six treatments. Excellent control was obtained in two messes with treatments applied just before they closed in the evening

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# Comparative Effect of Systox and Schradan on Some Predators of Aphids in Egypt[1]

MOSTAFA KAMAL AHMED[2]

It is thought that natural enemies can be saved when systemic insecticides are applied by a certain way to control the pests without exposing their enemies to the spray or its residue.

The purpose of this study is to compare the toxic effects of the two systemic insecticides Systox and schradan on some predators when fed on aphids killed by one of those two insecticides.

REVIEW OF LITERATURE.—Ripper *et al.* (1949) reported that the adults of the two coccinellids, *Coccinella septempunctata* and *Adalia bipunctata* survived feeding on moribund aphids from plants sprayed with schradan, and that larvae of *Syrphus* sp. were usually not killed by spray in field trials.

Ripper *et al.* (1950) stated that "Predacious insects are not killed by schradan, owing to the lack of contact effect. Adult Coccinellids and larvae of Syrphids are unharmed by contact or by feeding upon aphids that have died from the poison."

Ripper *et al.* (1951) cited that *Coccinella septempunctata* and Syrphid larvae were not killed when exposed on plants after soil treatment with schradan for the control of the cabbage aphid, *Brevicoryne brassicae* (L.).

Reynolds *et al.* (1953) reported that *Orius tristecolor* (White) was the only species affected of several beneficial insects in cotton when it was sprayed with Systox.

Ahmed *et al.* (1954) found that the larvae of three species of Syrphidae, *Baccha clavata* (F.), *Metasyrphus wiedemanni* (Johnson) and *Allograpta obliqua* (Say) were highly affected when fed on cotton aphids killed by Systox without external contact. They also studied the effect of these poisoned aphids on five species of coccinellids and showed that the susceptibility of the larvae ranged from 100 per cent in *Scymnus haemorrhous* Lec. to 3.7 per cent in *Coleomegilla maculata* (Deg.). The adults were not affected except for *Cycloneda sanguinea* (L.) of which 56 per cent were killed. Larvae of *Chrysopa rufilabris* Burmeister and *C. oculata* Say were practically immune to Systox, and only 2 per cent were affected when fed on the poisoned aphids.

MATERIALS AND METHODS.—Leaves of cotton and okra heavily infested with the cotton aphid, *Aphis gossypii* Glover, were collected from the field and treated with Systox[3] (principally, O,O-diethyl-O-2-ethylmercaptoethyl thiophosphate) or with schradan.[4] Systox was diluted one part of the active ingredient to 1600 parts of water, but schradan was diluted only 1:800. The poisoned aphids needed to feed the predators were prepared by two different methods of application.

[1] Accepted for publication April 5, 1955.

[2] Lecturer of Entomology, College of Agriculture, Cairo University, Giza, Egypt.

[3] Furnished by Farbenfabriken Bayer, Leverkusen, Germany.

[4] Furnished by Monsanto Chemical Company, St. Louis, Mo.

**Table 1.—The effect of feeding several species of predaceous larvae on cotton aphids killed with Systox or schradan by the dipping method.**

| SPECIES AND INSTAR | TREATMENT | NO. INDIVIDUALS TESTED | NO. DIED AFTER DAY INDICATED | | | | | | | PER CENT KILLED |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1st | 2nd | 3rd | 4th | 5th | 6th | 7th | |
| *Sphaerophoria flavicauda* (Middle) | Systox | 60 | 49 | 11 | | | | | | 100 |
| | schradan | 60 | 43 | 9 | 0 | | | | | 86.66 |
| | check | 60 | 0 | 0 | 0 | | | | | |
| *Leucopis puncticornis* (Middle) | Systox | 50 | 50 | | | | | | | 100 |
| | schradan | 50 | 22 | 16 | 3 | 0 | | | | 82 |
| | check | 50 | 0 | 0 | 0 | 0 | | | | |
| *Coccinella undecimpunctata* (First) | Systox | 100 | 100 | | | | | | | 100 |
| | schradan | 100 | 0 | 0 | 2 | 0 | 3 | 0 | 0 | 5 |
| | check | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| *Coccinella undecimpunctata* (Last) | Systox | 40 | 0 | 12 | 22 | 6 | | | | 100 |
| | schradan | 40 | 0 | 0 | 0 | | | | | 0 |
| | check | 40 | 0 | 0 | 0 | | | | | |
| *Scymnus syriacus* (First) | Systox | 80 | 71 | 9 | | | | | | 100 |
| | schradan | 80 | 0 | 2 | 2 | 1 | 1 | 0 | 0 | 6.4 |
| | check | 80 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | |
| *Scymnus syriacus* (Last) | Systox | 50 | 0 | 10 | 21 | 8 | 11 | | | 100 |
| | schradan | 50 | 0 | 0 | 1 | 0 | 0 | | | 2 |
| | check | 50 | 0 | 0 | 0 | 0 | 0 | | | |
| *Chrysopa vulgaris* (First) | Systox | 84 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 2.4 |
| | schradan | 84 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | check | 84 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |

1. *The dipping method.*—The blades of the infested leaves were dipped quickly in the diluted insecticide then shaken several times to let any excess of the material drop off the leaves. Then the leaves were placed lower surface up on a sheet of blotting paper. By this method the equal areas of leaves would get nearly the same amount of the insecticide. The predators were only allowed to feed on moribund or dead aphids. This required ½ hour for Systox and almost 3 hours for schradan probably because of its poor contact effect.
2. *The submerged petiole method.*—In this method glass vials were used, each containing the diluted insecticide and stoppered with a cork having a hole in the center sufficient to admit the petiole of the leaf. Each vial was 3 inches long and 1 inch in diameter. The infested leaf was clipped off the plant and quickly its petiole was submerged in the insecticide through the hole of the cork. In this way the blades of the leaves would have no chance of contamination with the material. The vials were placed on their sides over a sheet of clean paper with the lower surfaces of the blades upward. This position helped keep the moribund aphids from dropping off the leaves. The aphids died after 5 hours without any external contact with the insecticide.

The killed aphids were brushed from the treated leaves onto an untreated leaf placed in a petri dish. Not more than five predators were placed in each dish. A piece of paper was fitted inside the cover of each dish to keep the insects near their food instead of being attracted by the light to the tops of the dishes. Control experiments were conducted by feeding the predators on unpoisoned aphids. A fresh supply of food was given the predators once each day for a period of 1 week. Counts were made each day of the living, moribund, and dead predators and of those that had pupated. All the pupae were considered alive since normal adults emerged from them. Abbott's formula (1925) was used in calculating the percentage kill.

The middle larval instars of *Sphaerophoria flavicauda* Zett. (Syrphidae) and of *Leucopis puncticornis* F. (Ochthiphilidae), used in the tests were collected from the cotton and okra plants in the field. Two species of coccinellids, *Coccinella undecimpunctata* L., and *Scymnus syriacus* Mars. were reared in screen cages 12 by 12 by 12 inches in size. Cotton sprigs heavily infested with cotton aphids were put in a jar containing water and placed inside the cage. The sprigs were renewed every other day and the deposited eggs were removed to petri dishes. Eggs of *Chrysopa vulgaris* Schn. were collected from cotton fields and also kept in petri dishes until hatching. First instar larvae of coccinellids and *Chrysopa* were used in all tests except in the case of coccinellids where full grown larvae were also used.

DISCUSSION OF RESULTS.—Larvae and adults of all tested species except *Chrysopa* were highly susceptible to Systox when fed on aphids treated by the dipping method. Most of them died within 24 or 48 hours (Tables 1 and 2). Only the full grown coccinellid larvae became moribund after the first day of feeding, and all died within 5 days (Table 1). *Chrysopa vulgaris* larvae were able to survive the treatment and only 2.4 per cent were killed (Table 1). They were not affected even when they were fed from hatching till pupation on aphids killed by contacting Systox.

On the other hand, aphids killed by schradan—by the same dipping method—were not generally as poisonous as those killed by Systox except to the larvae of *Sphaerophoria flavicauda* and *Leucopis puncticornis*. Most of them died within 24 hours (Table 1). Not more than 6.4 per cent of the coccinellid larvae and half this percentage of the adults were affected (Tables 1 and 2). *Chrysopa* larvae were immune and none of them died.

Although aphids killed by the second method of application with either of the two insecticides were less harmful to the predators, yet larvae of *Sphaerophoria flavicauda*, and of *Leucopis puncticornis* were still highly susceptible. Both insecticides were almost equally poisonous to these two dipterous species; 85.2 per cent and 83.3 per cent of *S. flavicauda* larvae and 72 per cent and 66 per cent of *L. puncticornis* larvae were killed by Systox and schradan, respectively (Table 3).

First instar larvae of coccinellids when fed on the poisoned aphids were less affected by schradan than by Systox, but the middle aged and full grown larvae were not affected even by Systox (Table 3). Also the adults of the two coccinellids and the *Chrysopa* larvae were not harmed by either of the two insecticides. Only 2 per cent of the adults of *Coccinella undecimpunctata* were affected by Systox (Table 4).

SUMMARY.—The effects of Systox and schradan on predaceous insects were studied by feeding them on cotton aphids poisoned by one of these two insecticides with or without external contact.

Larvae of *Sphaerophoria flavicauda* and *Leucopis puncticornis* were very susceptible to both groups of cotton aphids (poisoned with or without external contact) which were killed by either of the two insecticides. Larvae and adults of coccinellids as well as those larvae

Table 2.—The effect of feeding two species of coccinellid adults on cotton aphids killed with Systox or schradan by the dipping method.

| SPECIES | TREATMENT | NO. INDIVIDUALS TESTED | NO. DIED AFTER DAY INDICATED | | | | | | | PER CENT KILLED |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1st | 2nd | 3rd | 4th | 5th | 6th | 7th | |
| *Coccinella undecimpunctata* | Systox | 50 | 50 | | | | | | | 100 |
| | schradan | 50 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 |
| | check | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| *Scymnus syriacus* | Systox | 63 | 19 | 21 | 9 | 14 | | | | 100 |
| | schradan | 63 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 3.2 |
| | check | 63 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |

**Table 3.—The effect of feeding several species of predaceous larvae on cotton aphids killed by Systox or schradan without external contact.**

| Species and Instar | Treatment | No. Individuals Tested | No. Died After Day Indicated | | | | | | | Per Cent Killed |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1st | 2nd | 3rd | 4th | 5th | 6th | 7th | |
| *Sphoerophoria flavicauda* (Middle) | Systox | 54 | 35 | 9 | 2 | 0 | | | | 85.2 |
| | schradan | 54 | 27 | 12 | 3 | 3 | | | | 83.3 |
| | check | 54 | 0 | 0 | 0 | 0 | | | | |
| *Leucopis puncticornis* (Middle) | Systox | 50 | 16 | 12 | 8 | | | | | 72 |
| | schradan | 50 | 22 | 8 | 3 | | | | | 66 |
| | check | 50 | 0 | 0 | 0 | | | | | |
| *Coccinella undecimpunctata* (First) | Systox | 100 | 13 | 6 | 11 | 0 | 0 | 0 | 0 | 27.8 |
| | schradan | 100 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 1.03 |
| | check | 100 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | |
| *Coccinella undecimpunctata* (Last) | Systox | 50 | 0 | 0 | 0 | | | | | 0 |
| | schradan | 50 | 0 | 0 | 0 | | | | | 0 |
| | check | 50 | 0 | 0 | 0 | | | | | |
| *Scymnus syriacus* (First) | Systox | 80 | 4 | 11 | 0 | 0 | 1 | 0 | 0 | 20 |
| | schradan | 80 | 0 | 3 | 1 | 0 | 0 | 0 | 0 | 5 |
| | check | 80 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| *Scymnus syriacus* (Last) | Systox | 50 | 0 | 0 | 0 | | | | | 0 |
| | schradan | 50 | 0 | 0 | 0 | | | | | 0 |
| | check | 50 | 0 | 0 | 0 | | | | | |
| *Chrysopa vulgaris* (First) | Systox | 65 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| | schradan | 65 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | check | 65 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | |

**Table 4.—The effect of feeding two species of coccinellid adults on cotton aphids killed with Systox or schradan without external contact.**

| Species | Treatment | No. Individuals Tested | No. Died After Day Indicated | | | | | | | Per Cent Killed |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1st | 2nd | 3rd | 4th | 5th | 6th | 7th | |
| *Coccinella undecimpunctata* | Systox | 50 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 2 |
| | schradan | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | check | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| *Scymnus syriacus* | Systox | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | schradan | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | check | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |

of *Chrysopa vulgaris* were not affected by both groups of aphids when killed with schradan.

The method of applying Systox was very important in the case of coccinellids. The aphids which had an outside contact with Systox were extremely poisonous to the coccinellid larvae and adults; 100 per cent of both were killed. Even all the full grown larvae became moribund 24 hours after feeding. The other group of aphids poisoned without external contact with Systox affected only 2 per cent of the adults of *Coccinella undecimpunctata* and not more than 27.8 per cent of its larvae.

Larvae of *C. vulgaris* were practically immune to Systox when fed on aphids of either group.

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# Control of Sugarcane Termites[1] (1946–1953)[2]

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Termites are a serious pest in localities that have light soil and are not subject to flooding, or at least waterlogging, for several weeks in the year. The list of crops damaged by them is rather large, but sugarcane appears to be particularly favored, and gives them a continuous supply of rich food throughout the year from the time the seed pieces are planted in the soil till the stubbles are removed after harvest. In cases of severe infestation no harvestable crop is ultimately left. Such events have actually happened despite usual irrigations, good rainfall and even applications of large amounts of BHC at planting. On the basis of surveys conducted over several years throughout the sugar growing tracts of Bihar, the loss is estimated at 2.5% in tonnage of the crop and 4.47% in sugar output. The state of Bihar has an estimated 0.3 million acres under sugarcane, yield 15 tons per acre or 1.5 tons sugar per acre. Thus this loss calculated at the current prices—$7.50 per ton for sugarcane and $161.00 per ton for sugar—amounts to a total annual loss of $4 million; of which $850 thousand is shared by the grower and $3,150,000 by the millers. Present methods of termite control in India are not very successful. These include all sorts of measures, such as digging out and destroying the queen termite; spreading moist trash to attract termites and then burning it; coal-tarring cut end of seed pieces (which were earlier considered particularly vulnerable); use of oilcake of *Melia azadiracta* seeds as manures; chopped Calotropis leaves in irrigation water; or chemicals, such as crude oil emulsion, arsenates, sulphocarbonates, phenyl, compounds of copper and mercury, DDT, BHC, and nabam. A good brief review of these efforts has been given by Narayanan (1952). The protection given by these measures was always poor and short-lived. In many cases, experimental results refer to places where termite incidence was naturally too low to give dependable results and when tested under conditions of severe infestation, as at Pusa, they failed. This indicated that more studies on biology and control, to find out the best formulation, dose, and method of application of insecticide, were needed.

Biological Observations.—The species widely occurring at Pusa is *Microtermes obesi* Holmgr. These favor damp but not waterlogged conditions in the soil. Hence, their colonies are easily located during the rainy season on the sides of raised embankments and irrigation channels. From the spread of infested patches it appears that they flourish in the uncultivated portions such as roads, embankments and channels, from where they spread out into the adjacent fields. The young queen cells are dome-shaped with a flat floor and a labyrinth of intercommunicating galleries and cells. Some of these contain "Fungus Gardens" swarming with young insects. The fact that these "Fungus Gardens" are produced even in colonies transplanted without them in captivity shows that they are in some way either carried or produced by the termites themselves. The eggs and workers can be seen all the year round, but the potential kings and queens are seen only a month or so before the monsoons set in. At this stage these appear as nymphs with large wingpads. With the outbreak of the monsoons, when the ground has become soaked and soft by an early shower or two, the colonizing flight takes place. Holes large enough to permit one winged termite to crawl out at a time, appear in the soil and the soldiers and workers emerge first and spread out on the surrounding soil, trash and vegetation as if to ensure safety to the royal processions. Then, one by one, the winged ones start emerging in great rush and excitement and fly straight away. Some of the soldiers, that stay inside the edge of the hole, close it immediately after the last adult has emerged so as to make it indistinguishable from the surrounding spot. The small proportion of the winged termites that survive destruction by birds, lizards, lights and other causes, later alight on the ground, shed their wings at the humeral suture and proceed in pairs to found new colonies, the male closely following the female. The noticeable damage to the crops is caused by the workers feeding upon them. The seed pieces are attacked at the cut ends and the nodal annulus with almost equal preference hence trying to protect the cut ends only is apt to be of little benefit. Destruction of the buds causes failure of germination and in severe cases the seed piece may be reduced to a stick of clay cartoned over with its papery remains of the rind. In young shoots the damage is limited to the basal solid portions and kills off the plant easily. Grownup canes may keep standing, if supported by adjacent canes, and show a few green leaves at the top even till most of the internal tissues have been eaten and replaced by mud. Mud filling appears to conserve moisture, so essential for their life, gives support to the plant being fed upon, and excludes light and enemies. Sometimes the harder nodal part is just bored through, and not completely eaten up, to reach the next internode.

Methods.—The assessment of the results of the experiments on the control of these termites is based generally on three criteria, viz, germination, periodical incidence, and yield of sugarcane. At times, examination of seed pieces after the completion of germination and the count of millable canes harvested were also made. Germination counts were made progressively, every week until complete; after which, if desired, seed pieces from ungerminated portions were dug out and examined for the extent of failure accounted for by termite attack. Afterwards, 1% of the crop from each plot distributed in random units and rows of crop, was uprooted weekly, each cane split longitudinally and the percentage of termite incidence recorded. This was done at harvest also, when yield of cane and, if desired, the number of millable canes per plot were also recorded. The results of incidence

[1] *Microtermes obesi* Holmgr. and *Odontotermes assmuthi* Holmgr.

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observations were pooled into three periods for study, viz, pre-monsoon, from the beginning of crop season till mid-June; monsoon from the mid-June till mid-September; and post-monsoon, from mid-September till harvest. Besides these the total incidence throughout the year was also considered. Minor variations, wherever made, are shown in the tables of data.

RESULTS OF TESTS, 1946–51.—Among the modern insecticides[4] DDT and BHC were the first to be available and used. BHC was supplied in various formulations under the trade names of Agrocide and Gammexane by the Imperial Chemical Industries (India) Ltd. DDT was obtained from Messrs. Geigy Ltd. as technical or wettable powders 50%; toxaphene became available later from Hercules Powder Co.; and parathion under the trade name of Rhodiatox from Rhone Poulenc, Paris. Aldrin and dieldrin were supplied by Julius Hyman & Co., U.S.A. (now Shell Chemical Corporation) for 1952 trials.

In one of the earlier experiments conducted for 3 years (1947–1949) under the aegis of the Indian Central Sugarcane Committee, lead arsenate @ 6.67 lbs./acre as 5% suspension, mercuric chloride @ 2.08 lbs./acre as 0.25%, and DDT @ 37.5 lbs./acre as 0.5%, were used for soaking the seed pieces before planting for 15 minutes (Table 1).

It was concluded that all three treatments, particularly lead arsenate, gave some protection against termites during the germination period of the crop; but lead arsenate caused poor germination. At harvest time there was no significant difference between the various treatments with respect to incidence of termites, indicating that they gave only a short period of amelioration. Significant increase in yield over the control was obtained with mercuric chloride only one year.

In another series of experiments which ran for 7 years, various formulations giving graded dosages of BHC were used. The applications during (1946–1951) were: (1) dusting to only the cut ends of seed pieces (15 lb. dust/acre) @ 0.05 and 0.15 lb./acre gamma isomer of BHC, of which the lower dose was discarded as inadequate after the first year; (2) as a suspension or emulsion bath for soaking or dipping (50 gallons/acre) of seed pieces before planting, @ 0.16, 0.33, and 0.49 lb./acre of which the lowest dose was discarded after the first year as being inadequate, and the highest ran for only the first 2 years; and (3) as suspension or dust sprinkled over seed pieces lying exposed in furrows, immediately before covering them with soil, @ 0.98 lb./acre (Table 2). These experiments terminated in 1951 but were restarted in modified form at the request of the Imperial Chemical Industries. In this latter case the BHC treatments consisted of 0.78 lb./acre of gamma isomer applied as in method (2) above; and 0.1, 0.16, and 0.33 lb./acre as dusts applied as in method (3) above (Table 3).

With respect to germination, in 4 out of 7 years significant advantage was obtained by one or the other treatment of BHC and the higher the dosage the better were the planted seed pieces protected against termite attack. Judging from the incidence of termites during the rest of the crop season, 0.98 lb. gamma isomer (equivalent to 150 lbs. of 5% BHC dust) gave some protection for about 4 months only while soaking of seed pieces to give 0.33 or 0.485 lbs. gamma isomer per acre was much less effective. In 1953 none of the treatments gave the desired protection and the experiment had to be abandoned as early as October that year. Yields were significantly higher only in one year (1946–47) out of seven and then too the result loses dependability because very few canes were left harvestable that year. Thus the application of even the highest amount of BHC in these trials guaranteed no definite ultimate gain though it cost the farmer an equivalent of 1.3 tons or approximately 9% of his crop.

The treatment of cut ends of seed pieces failed because it was based on a wrong idea; while soaking or dipping of seed pieces, besides being impracticable to Indian farmers and wasteful, precluded uniform and adequate application because suspensions settle quickly and some of the active ingredients are drained out after the seed pieces are taken out of the bath. Application was best made to seed pieces lying in open furrows immediately before covering them with soil. Finally, the fact that BHC phytotoxicity may last in soils for years, though its action against termites was of an ephemeral nature, deserves consideration.

1952–54 RESULTS.—During these two years success was finally achieved. The approach was to introduce large numbers of available modern insecticides in pilot trials (not discussed here) in various doses and follow up by trying out in proper field trials such treatments as appeared promising. To prolong the period of protection if the basic treatment given at the time of planting appeared inadequate, 0.98 lb. gamma isomer of BHC/acre was applied close to the clumps as a suspension in water during July. In 1951–52 the treatments consisted of 15 lbs./acre DDT and 10 lb./acre of toxaphene, both with and without subsequent applications of BHC as above; 0.98 lb./acre gamma isomer of BHC in the form of a suspension and of a dust and 1.2 lbs./acre parathion with only subsequent application of BHC. In the next year the

**Table 1.—Effects of treatment of seed pieces with lead arsenate, mercuric chloride, and DDT in preventing termite damage to sugarcane crop.**

| CRITERIA | YEARS | SEED PIECES SOAKED FOR 15 MINUTES IN | | | CONTROL | CRITICAL DIFFERENCE AT 5% LEVEL[a] |
|---|---|---|---|---|---|---|
| | | Lead Arsenate | Mercuric Chloride | DDT | | |
| Germination | 1947–48 | 23.2 | 26.1 | 36.1 | 31.3 | 5.8 |
| | 1948–49 | 44.2 | 50.1 | 44.8 | 41.1 | 4.9 |
| | 1949–50 | 38.9 | 34.5 | 43.6 | 30.8 | 4.52 |
| Average | | 35.4 | 36.9 | 41.5 | 34.4 | |
| Percentage incidence to seed pieces | 1947–48 | 2.1 | 7.6 | 3.2 | 10.6 | 3.9 |
| | 1948–49 | 3.6 | 2.0 | 0.3 | 10.0 | 2.86 |
| | 1949–50 | 1.5 | 2.9 | 2.6 | 4.0 | |
| Average | | 2.4 | 4.2 | 2.0 | 8.2 | |
| Percentage incidence at harvest | 1947–48 | 65.0 | 71.5 | 70.7 | 70.2 | |
| | 1948–49 | 51.5 | 45.7 | 45.9 | 58.1 | |
| | 1949–50 | 1.8 | 5.2 | 2.3 | 3.9 | |
| Average | | 42.8 | 40.8 | 39.6 | 42.4 | |
| Yield sugar cane tons/A. | 1947–48 | 0.9 | 1.1 | 1.7 | 1.0 | |
| | 1948–49 | 21.5 | 23.1 | 25.2 | 22.5 | |
| | 1949–50 | 25.8 | 29.3 | 25.2 | 23.3 | 3.85 |
| Average | | 16.1 | 17.6 | 17.4 | 15.6 | |

[a] All incidence figures have been transformed to angles.

[4] The author is grateful to all those firms who liberally helped with samples of insecticides and provided advice and assistance. He is particularly grateful to Dr. A. M. Boyce, Director, Citrus Experiment Station, Riverside, California, for his constant guidance and help in procuring aldrin and dieldrin.

**Table 2.—Effects of various treatments with BHC[a] in preventing termite damage to sugarcane.[b]**

| Criteria | Years | Cut Ends Dusted | | Seed Pieces Soaked | | | Seed Pieces in Furrows Treated | | No Treatment | Critical Difference at 5% Level |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 0.05 lb./A. | 0.15 lb./A. | 0.16 lb./A. | 0.33 lb./A. | 0.49 lb./A. | (suspension) 0.98 lb./A. | (dust) 0.98 lb./A. | | |
| Germination | 1946–47 | 36.3 | 35.2 | 32.0 | | 34.4 | | | 39.2 | |
| | 1947–48 | | 33.3 | | 35.2 | 32.0 | 39.6 | 36.1 | 36.9 | 7.41 |
| | | | | | | 24.2[c] | | | | |
| | 1948–49 | | 68.4 | | | | 56.3 | 59.5 | 47.9 | 13.20 |
| | 1949–50 | | 53.7 | | 57.4 | | | 41.8 | 46.8 | — |
| | 1950–51 | | 33.2 | | 63.5 | | 35.7 | 54.3 | 44.3 | 10.56 |
| *Percentage incidence* | 1946–47 | 16.5 | 13.3 | 17.7 | | 10.1 | | | 11.9 | — |
| | 1947–48 | | 30.5 | | 26.1 | 22.9 | 16.7 | 15.8 | 27.7 | 8.96 |
| Pre-monsoon | | | | | | 21.3[c] | | | | |
| | 1948–49 | | 17.1 | | | | 13.4 | 10.8 | 16.1 | — |
| | 1949–50 | | 10.5 | | 7.3 | | | 5.0 | 8.7 | — |
| | 1950–51 | | 21.3 | | 19.7 | | 9.2 | 13.2 | 24.6 | 6.62 |
| Monsoon | 1946–47 | 20.0 | 14.6 | 23.4 | | 14.4 | | | 20.4 | — |
| | 1947–48 | | 37.7 | | 36.7 | 25.0 | 32.2 | 29.1 | 25.7 | 6.78 |
| | | | | | | 34.6[c] | | | | |
| | 1948–49 | | 39.3 | | | | 38.2 | 32.3 | 37.4 | — |
| | 1949–50 | | 13.5 | | 9.9 | | | 5.1 | 11.6 | 6.79 |
| | 1950–51 | | 45.5 | | 43.3 | | 40.1 | 44.8 | 39.0 | — |
| Post-monsoon | 1946–47[d] | | | | | | | | | |
| | 1947–48 | | 43.9 | | 41.2 | 51.7 | 61.1 | 50.7 | 45.8 | 9.88 |
| | | | | | | 44.4[c] | | | | |
| | 1948–49 | | 37.8 | | | | 42.8 | 42.5 | 40.2 | — |
| | 1949–50 | | 12.9 | | 8.0 | | | 6.4 | 15.8 | 5.91 |
| | 1950–51 | | 52.8 | | 51.3 | | 45.4 | 50.2 | 42.9 | — |
| Over all | 1946–47 | 19.0 | 14.6 | 21.8 | | 13.2 | | | 17.6 | — |
| | 1947–48 | | 36.8 | | 33.9 | 30.3 | 37.2 | 32.7 | 35.8 | 3.92 |
| | | | | | | 33.6[c] | | | | |
| | 1948–49 | | 31.3 | | | | 30.7 | 29.0 | 31.3 | — |
| | 1949–50 | | 12.6 | | 3.7 | | | 5.3 | 13.0 | 7.03 |
| | 1950–51 | | 38.5 | | 39.8 | | 36.9 | 38.8 | 36.8 | — |
| Yield (Ton/A.) | 1946–47 | 4.3 | 4.1 | 11.2 | | 14.0 | | | 4.4 | 5.96 |
| | 1947–48 | | 1.5 | | 2.4 | 1.8 | 3.5 | 4.5 | 2.7 | 2.36 |
| | | | | | | 1.2 | | | | |
| | 1948–49 | | 21.7 | | | | 24.2 | 23.9 | 17.7 | — |
| | 1949–50 | | 23.4 | | 22.3 | | | 21.8 | 21.2 | — |
| | 1950–51 | | 9.5 | | 13.6 | | 14.4 | 13.8 | 10.3 | 4.86 |

[a] All doses indicated are in terms of gamma isomer of BHC.
[b] All the percentage values have been transformed to angles.
[c] Formulation used was wettable powder containing 50% BHC; the other formulation used in 1947–48 gave same dose but was prepared from technical BHC (D919).
[d] Complete data not available because in several plots no canes were left standing by the termites.

treatments with DDT and toxaphene without subsequent reinforcement with BHC and parathion were rejected while two new treatments, viz. aldrin 2.3 lbs./acre and dieldrin 0.32 lb./acre as water emulsions were included. All these were applied to seed pieces lying exposed in furrows at the time of planting. The data are presented in table 4 for the first year and in table 5 for the second year trials.

GERMINATION.—In the first year (Table 4) there was no significant difference in any of the treatments with respect to germination. Actual figures show slight appreciation in all treatments except BHC suspension which was unaccountably a little inferior to control. Germination in the next year (Table 5) was better in every treatment than control and these differences were highly significant. Aldrin, dieldrin, or BHC (dust) gave more than 100% more germination, and the first two were the best. This was confirmed by examination of infestation of seed pieces which testifies to the outstanding superiority of aldrin (4.3% only as against 79.3% in control).

*Seasonal Incidence.*—In the first year (Table 4) significant differences in this regard were seen only till the monsoon period in the highest dose of BHC in either form. In the earlier pre-monsoon period all the treatments were better than the control; those of BHC and toxaphene being significantly so. The effectiveness of the treatments was fast vanishing, with only slight advantage in the cases in which subsequent applications of

**Table 3.—Effect of various treatments with BHC in preventing termite damage to sugarcane.[a]**

| Criteria | Years | Seed Pieces Dipped 0.78 Lb./Ac. | Seed Pieces in Furrows Treated with BHC Dust | | | No Treatment | Critical Difference at 5% |
|---|---|---|---|---|---|---|---|
| | | | 0.33 Lb./Ac. | 0.16 Lb./Ac. | 0.10 Lb./Ac. | | |
| Germination, % | 1952–53 | 42.2 | 39.4 | 41.5 | 41.4 | 33.9 | 5.15 |
| | 1953–54 | 31.7 | 32.7 | 31.0 | 31.8 | 22.1 | 5.32 |
| *Percentage incidence* | | | | | | | |
| In seed pieces | 1952–53 | 39.6 | 21.0 | 21.3 | 41.7 | 43.0 | 18.4 |
| | 1953–54 | 72.5 | 52.2 | 52.5 | 61.5 | 84.7 | 15.92 |
| Shoots/A. at mid-July | 1952–53 | 22,668 | 24,432 | 22,206 | 24,696 | 19,536 | — |
| | 1953–54 | 10,758 | 13,098 | 12,030 | 11,226 | 5,256 | — |
| *Percentage incidence* | | | | | | | |
| Harvest | 1952–53 | 38.2 | 54.2 | 49.1 | 34.4 | 27.2 | 14.28 |
| Pre-monsoon | | 53.8 | 29.0 | 34.6 | 41.3 | 53.1 | 13.71 |
| Monsoon | | 68.9 | 65.8 | 72.0 | 70.9 | 67.8 | — |
| Post-monsoon | 1953–54 | 54.6 | 58.4 | 55.8 | 64.4 | 68.6 | — |
| Harvest | | 44.6 | 76.0 | 55.6 | 58.3 | 62.5 | — |
| Millable canes/A. | 1952–53 | 14,694 | 14,016 | 13,206 | 14,856 | 13,374 | — |
| | 1953–54 | 258 | 414 | 210 | 234 | 150 | — |
| Yield (tons/A.) | 1952–53 | 5.3 | 6.1 | 4.9 | 6.1 | 4.8 | — |
| | 1953–54 | 0.1 | 0.2 | 0.1 | 0.1 | 0.1 | — |

[a] All percentage figures have been transformed to angles; dosages are in terms of gamma isomer of BHC.

BHC were made. Hence in the post-monsoon period none of the treatments showed less infestation than the control; nor was there any significant difference over the entire year. In the next year's trial (Table 5) aldrin and dieldrin maintained their outstanding superiority throughout the year and the differences were always significant at the 1% level. In no season was termite incidence more than 2.9% in aldrin and 19.9% in dieldrin treatments while it was 88.7% in the control and 68.5% in BHC (post-monsoon period). A slight improvement was observed in the BHC, DDT and toxaphene treatments by subsequent applications of BHC in July, but these were not significant for toxaphene in any period and not for DDT in the monsoon period. Even these double insecticidal treatments were not nearly as effective as those obtained during the same period by only one application of aldrin or dieldrin. DDT, even at the highest dose, was of no avail.

*Yield of Sugarcane.*—In 1951–52 every treatment recorded higher yield than the control, the highest being in the 0.98 lb./acre gamma isomer of BHC treatment; but none of these differences were significant. In 1952–53 increases in yield were highly significant. The best treatments in this respect were aldrin and dieldrin again. In these cases the yield was at least 4.25 tons/acre more than that in the control. The yields in other treatments in which a supplementary dose of 0.98 lb./acre of the gamma isomer of BHC was applied in July, were also significantly better than the control but far inferior to those obtained in the aldrin or dieldrin treatments (Table 5). Hence,

**Table 4.—Effects of DDT, BHC, toxaphene, and parathion when applied to sugarcane seed pieces in furrows at planting (with and without a subsequent application of BHC in July) to prevent termite damage.[a]**

| Criteria | DDT as Dust | DDT +BHC | Toxaphene | Toxaphene +BHC | BHC Dust +BHC | BHC Suspension +BHC | Parathion +BHC | Control (No Treatment) | Critical Difference at 5% |
|---|---|---|---|---|---|---|---|---|---|
| Germination, % | 28.1 | 23.0 | 25.9 | 23.8 | 15.4 | 21.3 | 25.8 | 21.5 | — |
| *Percentage incidence* | | | | | | | | | |
| Pre-monsoon season | 15.8 | 13.6 | 8.1 | 12.5 | 7.3 | 8.9 | 12.8 | 17.8 | 6.0 |
| Monsoon | 20.5 | 20.5 | 19.8 | 15.0 | 9.9 | 12.3 | 25.5 | 14.0 | 9.12 |
| Post-monsoon | 43.3 | 47.0 | 49.7 | 48.3 | 43.6 | 48.6 | 55.9 | 42.9 | — |
| Over all | 29.5 | 30.9 | 22.6 | 28.9 | 25.4 | 28.2 | 33.3 | 28.8 | — |
| Yield (tons/A.) | 12.9 | 18.7 | 15.9 | 15.4 | 12.5 | 22.4 | 14.2 | 11.8 | — |

[a] All figures of incidence have been transformed to angles.

Table 5.—Effects of DDT, toxaphene, BHC, aldrin, and dieldrin applied at planting time to prevent termite damage to sugarcane.[a]

| CRITERIA | BHC DUST | BHC SUSPENSION | BHC SUSPENSION +BHC[b] | TOXAPHENE DUST | TOXAPHENE DUST +BHC[b] | DDT DUST | DDT DUST +BHC[b] | DDT BATH | DDT BATH +BHC[b] | ALDRIN EMULSION | DIELDRIN EMULSION | CONTROL (NO TREATMENT) | CRITICAL DIFFERENCE AT 5% |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Germination % | 40.3 | 33.0 | 33.0 | 38.0 | 38.0 | 29.5 | 29.5 | 40.0 | 40.0 | 44.4 | 45.8 | 19.1 | 9.01 |
| *Percentage incidence* | | | | | | | | | | | | | |
| To seed pieces | 10.9 | 29.1 | 29.1 | 23.8 | 23.8 | 67.0 | 67.0 | 48.4 | 48.4 | 4.3 | 12.2 | 79.3 | 21.50 |
| Pre-monsoon | 11.9 | 6.7 | 6.7 | 12.2 | 12.2 | 22.3 | 22.3 | 35.1 | 35.1 | 1.8 | 3.3 | 36.3 | 14.66 |
| Monsoon | 41.2 | 42.6 | 23.7 | 39.7 | 25.7 | 49.9 | 40.9 | 48.0 | 42.0 | 2.5 | 4.8 | 70.3 | 16.01 |
| Post-monsoon | 68.5 | 76.2 | 52.3 | 60.4 | 52.2 | 74.1 | 59.5 | 73.0 | 48.3 | 2.9 | 19.9 | 88.7 | 14.45 |
| Over all | 51.3 | 53.4 | 36.9 | 48.1 | 40.2 | 56.9 | 47.7 | 55.1 | 44.9 | 2.1 | 4.7 | 75.2 | 12.70 |
| Millable canes/A. | 70.9 | 44.3 | 89.8 | 79.8 | 116.0 | 38.8 | 57.7 | 30.5 | 100.5 | 219.5 | 224.1 | 15.8 | 56.77 |
| Yield (tons/A.) | 1.3 | 0.8 | 1.8 | 1.9 | 2.0 | 0.9 | 1.2 | 0.6 | 1.8 | 4.6 | 4.4 | 0.1 | 1.45 |

[a] All percentages have been transformed to angles.
[b] This application of BHC made in July.

from all criteria the best treatment was aldrin and the next best dieldrin. Other tests made on standing, termite-infested sugarcane, sugarcane seedlings, and pilot trials have bourne ample testimony to this fact. These tests have also suggested that dieldrin, with a little higher dose, could very well compete with aldrin if not surpass it in giving prolonged protection.

SUMMARY AND CONCLUSIONS.—Field observations indicated that *Microtermes obesi* Holmgr. needs damp soil conditions for its life but not waterlogged conditions. It cannot be controlled by the usual irrigations. The sugarcane seed pieces are attacked with almost equal preference at the cut ends and the nodal annulus.

Experiments on control were conducted in large fields in properly replicated and randomised plots with lead arsenate, mercuric chloride, DDT, BHC, toxaphene, parathion, aldrin and dieldrin. These were applied as a dip for seed pieces before planting, or to only the cut ends of seed pieces, or sprinkled over seed pieces lying exposed in furrows immediately before covering. The results were assessed by three criteria, viz. (1) protection given to seed pieces and buds to ensure better germination, (2) reduction in the incidence of termite attack to the crop after this period, and (3) the ultimate result these had in ensuring better yield.

Among lead arsenate, mercuric chloride and DDT at the dosages tried, DDT appeared to be the better of these. Lead arsenate was good so far as prevention of injury by termites was concerned but appeared to affect germination adversely.

Application of BHC at doses below 0.49 lb./acre gamma isomer, was of little utility and even the highest dose of 0.98 lb./acre gave some protection for only 3 to 4 months when it reduced the termite incidence, at most, by half. Afterwards the incidence increased greatly and there was no significant gain in yield of sugarcane.

Attempts to prolong the period of protection that BHC, DDT or toxaphene applied at the time of planting gave, by a subsequent application of BHC to the bases of the standing crop, showed little advantage.

Toxaphene in doses tried, gave results similar to 0.98 lb./acre gamma BHC, and DDT and parathion were of little use.

Aldrin and dieldrin proved to be the best insecticides for yearlong and almost complete protection of sugarcane crop from termites. The utility of aldrin and dieldrin has been confirmed by trials on sugarcane seedlings, and even on the standing crop that was being severely damaged by termites. These insecticides may be applied with success to all stages of the sugarcane crop against termites.

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# Insecticide Seed Treatment of Soybeans in Relation to Phytotoxicity and Seed-Corn Maggot Control[1,2]

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Insecticide seed treatment has been widely accepted by farmers in the Corn Belt as a valuable control measure against soil insects attacking germinating seed corn (Starks & Lilly 1955). Soybeans, which are damaged occasionally by phytophagous soil insects such as the seed-corn maggot, *Hylemya cilicrura* (Rond.), seldom are treated commercially with an insecticide before planting (Starks 1954). There is considerable literature pertaining to seed-corn maggot control with insecticide seed treatments on lima beans (Lange *et al.* 1951), but little is published on the value of these treatments on soybeans. The work reported here was intended to explore various dosages of effective insecticides in relation to seed protection, phytotoxicity, and compatibility with fungicide seed dressings and soybean bacterial inoculations. Experiments were conducted both under controlled conditions in the greenhouse where small differences in treatments could be accurately measured, and variable environments in the field which gave a more practical aspect to the results.

Materials and Methods.—The soybean seed lots used were grown for increase on college experimental farms in Iowa. They were threshed and cleaned by the usual mechanical procedures for this crop. Only uncracked seeds were used in these experiments. All the chemicals used were commercial preparations. All dry insecticides were applied with $2\frac{1}{2}$ milliliters of a $2\frac{1}{2}\%$ methyl cellulose solution per pound of seed by using a modified slurry procedure. Insecticide and fungicide dosages were calculated in ounces of actual ingredients per bushel of seed. The insecticides were usually wettable powder 25% formulations, and the wettable fungicide, captan, used in some tests was either a 50 or 75 per cent preparation. Emulsifiable concentrates were used in one test.

Treating and planting procedures were very similar to those reported in a paper pertaining to seed corn treatment (Starks & Lilly 1955). Some of the laboratory and greenhouse equipment used in these experiments is shown in figure 1. Mixing was by hand shaking and machine rotation of measured seed lots held in Mason fruit jars with 5 minutes of total agitation for each treatment. Seeds were coated with the sticker before the dry chemicals were added in two portions.

A randomized complete block design was used for all greenhouse tests. These experiments were in wood or metal flats containing washed river sand. The sand medium had the practical advantage of being easily removed from the roots, and it lacked organic matter which apparently moderates the toxic action of some insecticides. The same criteria for measuring treatment effects were used for soybeans as had been employed with corn, except that measurements of root lengths of soybeans seldom showed important differences.

Seeds for field plantings were counted in the laboratory on a counting board shown in figure 1, and placed in coin envelopes. They were inocculated with a commercial bacterial preparation 4 hours prior to planting if soybeans had not been grown in the field the previous year. Excessive inoculant was shaken with the seed in the coin envelope. Planting was usually in furrows approximately 2 inches deep. In most tests emergence was the only measure of the results.

Results and Discussion.—The data were analyzed statistically in some cases. Analysis of variance was used and the F test calculated to determine significance.

*Varietal sensitivity experiment.*—The object of this test was to determine whether or not any of five standard varieties of soybeans varied in their sensitivity to insecticide injury. The varieties used were Blackhawk, Hawkeye, Adams, Lincoln, and Clark. An excessive dosage of 4 ounces of BHC with 75 per cent gamma isomer content was slurried on a sample of each variety. Each insecticide treatment was compared with a control of the respective variety. To make the test more severe, the seed samples were treated and stored at room temperature for 4 months before they were germinated in the greenhouse. Final emergence and average green weight determinations are shown in table 1.

There was no appreciable damage by the insecticide to any of the five varieties. The final emergence among varieties varied, but the difference between the control and the insecticide treatment was not significant for any individual varieties. There were a few stunted plants in the BHC treatments but the reductions in average green weights for all varieties were of little practical importance especially considering the severity of the test. No differences could be detected in varietal response to BHC in the experiment as all five varieties apparently were highly tolerant of the treatment.

*Phytotoxicity tests in the field.*—A series of 12 treatments were slurried on a sample of Blackhawk soybeans grown in 1950 to determine the safeness of certain insecticides to the seed. Dosages for all treatments were equivalent to $1\frac{1}{4}$ ounces of actual toxicant per bushel. All materials were wettable powder formulations. On June 24, 1952 soon after the seed was treated, this series was planted in the insectary garden at Ames. Each plot consisted of 100 seeds planted in an 18-foot row with the rows spaced 2 feet apart. Space was available for eight replications, and daily emergence was recorded as a measure of treatment influence. Daily counts were continued from the fifth to the ninth day inclusive after planting. The last

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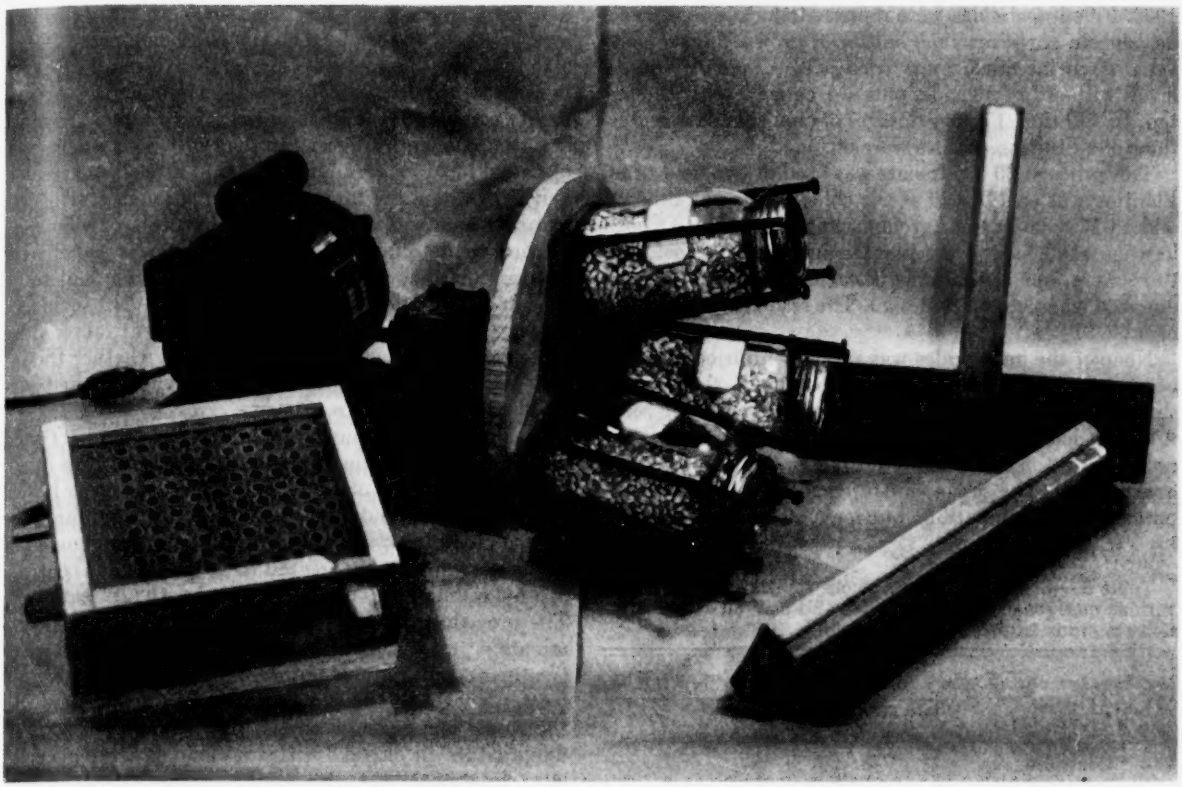

FIG. 1.—Laboratory equipment used for seed treatment experiments. Clockwise: Improvised counting board for soybeans, motor-driven mixer with quart jars containing seed, paddle used for smoothing sand in greenhouse flats, and board used for making planting trenches in flats containing sand.

count was considered as the total emergence. The treatments and results are presented in table 2.

DN-111 was so injurious that three replications of this treatment had no emerged seedlings; therefore, it was omitted from the statistical analysis. All of the insecticides except Ortho HL-609 and Benzahex (gamma isomer content was 75% of the total isomers and dosage was calculated on basis of gamma isomer content) significantly decreased final emergence and all significantly increased the mean emergence period. However, it should be emphasized that this seed lot was about 19 months old when tested.

Table 1.—Final emergence and average green weight data for five varieties of soybeans treated with an excessive dosage of BHC. 1954.

| VARIETY | PER CENT OF BHC TREATMENT BASED ON CORRESPONDING CONTROLS[a] | |
|---|---|---|
| | Final Emergence | Mean Green Weight (Gm.) |
| Hawkeye | 104 | 80 |
| Adams | 104 | 88 |
| Lincoln | 102 | 100 |
| Clark | 103 | 100 |
| Blackhawk | 102 | 94 |

[a] Each value represents the mean of 4 replications of 15 seeds each.

A second series of treatments was intended to give information on phytotoxicity under field conditions in

Table 2.—Summary of results from a phytotoxicity test with Blackhawk soybeans planted in the insectary garden, Ames—1952.

| TREATMENT[a] | MEAN NUMBER OF PLANTS EMERGED[b] | MEAN EMERGENCE PERIOD (DAYS)[b] |
|---|---|---|
| Control | 81.4 | 6.5 |
| Lindane | 71.0† | 7.1† |
| Ortho HL-609[c] | 84.3 | 6.9† |
| Benzahex[d] | 82.9 | 6.8* |
| Heptachlor | 63.9† | 7.0† |
| Aldrin | 68.4† | 6.8* |
| Dieldrin | 69.3† | 6.9† |
| EPN | 61.5† | 7.2† |
| NPD | 74.6* | 7.0† |
| Malathion | 44.5† | 7.4† |
| Metacide | 74.8* | 7.0† |
| DN-111[e] | 1.6† | — |
| * L.S.D. at the 5% level[f] | 6.5 | 0.3 |
| † L.S.D. at the 1% level[f] | 8.7 | 0.4 |

[a] The levels of all insecticides were equivalent to 1½ ounces of actual material per bushel of seed.
[b] Each value represents the mean of 8 replicates of 100 seeds each.
[c] A commercial formulation containing 25% lindane and 50% captan.
[d] BHC product of Chipman Chemical Co. Inc.
[e] Dinitro-o-cyclohexylphenol, dicyclohexylamine salt.
[f] For comparing treatment means with the control mean.

1953. Five insecticides were represented at various levels on Lincoln soybeans that had been grown the previous year. Each insecticide was tried at ½-, 1-, and 2-ounce levels without a fungicide, plus a 1-ounce level with captan. In addition, 1-ounce dosages of emulsifiable formulations of all the insecticides were included.

This series of 26 treatments was used in two field tests. Planting was on May 20 at the college farm at Ankeny, and on May 26 at the Agronomy farm at Ames. At both locations 100 seeds were planted in a 20-foot row, and there were four replications of each treatment in a randomized complete block design. The results are presented in table 3.

None of the insecticides was severely injurious to soybeans at either location. At Ames the 2-ounce levels showed a slight tendency to injure the germinating seed. A higher dosage than 2 ounces would not seem advisable, especially if the chemical were to be put on the seed as a dry mixture. The insecticide-fungicide combinations apparently were compatible, but none of them appreciably increased emergence when compared with the 1-ounce levels without fungicide. The emulsions compared favorably with the same levels of dry materials in all cases.

*Soybean injury experiment.*—In a preliminary experiment a combination lindane and captan treatment resulted in the integuments adhering to the cotyledons when seeds of an old lot were germinated in sand after being treated and stored at room temperature for 9 months. The test reported here was intended to explore this phenomenon further to determine if lindane alone was capable of causing the abnormality, or if the insecticide had to be used in combination with captan to give it. Also, evidence was needed to determine whether treatment followed by prolonged storage gave the response, or whether the injury was simply a reaction accompanying lowered viability of the seed due to old age.

A sample of Blackhawk seed which had been harvested approximately 15 months before treatment was used. Lindane at the rate of 4½ ounces of 25 per cent per bushel was used alone and in combination with captan. The dosage of captan was 4½ ounces of 50 per cent material. Untreated and captan-treated lots were used as controls. Methyl cellulose was used as a sticker with all treatments. The procedure was to store the seed and carry out germination tests in sand at about 6-week intervals after treatment until injury appeared, and then to freshly treat soybeans of the same seed lot for comparison with the stored lots during the next test. Storage was at room temperature in closed fruit jars. The seed intended for later treatment was also stored at room temperature. Each greenhouse test consisted of 5 replications with 25 seeds per treatment per row. Results are summarized in table 4.

The variability in emergence among treatments was not significant at the 5 per cent level in any of the tests.

**Table 3.—Stand counts of Lincoln soybeans treated with various dosages of five insecticides and planted at two locations to study insecticidal phytotoxicity. 1953.**

| Treatment[a] (Ounces) | Mean Stand Count[b] | |
|---|---|---|
| | Ames | Ankeny |
| Controls: | | |
| Untreated | 76.8 | 74.3 |
| Captan[c] | 76.0 | 75.0 |
| Lindane: | | |
| 2 | 70.8 | 73.5 |
| 1 | 73.5 | 75.5 |
| ½ | 74.0 | 74.5 |
| 1+captan | 75.8 | 80.0 |
| 1, Em. | 74.5 | 80.0 |
| Dieldrin: | | |
| 2 | 69.3 | 77.0 |
| 1 | 71.8 | 77.3 |
| ½ | 75.8 | 74.0 |
| 1+captan | 77.3 | 74.3 |
| 1, Em. | 71.8 | 77.5 |
| Heptachlor: | | |
| 2 | 67.8 | 76.8 |
| 1 | 73.3 | 79.5 |
| ½ | 75.0 | 76.0 |
| 1+captan | 74.3 | 75.8 |
| 1, Em. | 72.0 | 75.3 |
| Recrystallized aldrin: | | |
| 2 | 70.5 | 75.5 |
| 1 | 74.5 | 80.5 |
| ½ | 75.3 | 76.0 |
| 1+captan | 73.8 | 79.3 |
| 1, Em. | 75.3 | 77.0 |
| Diazinon: | | |
| 2 | 67.3 | 74.5 |
| 1 | 71.8 | 73.0 |
| ½ | 72.5 | 80.0 |
| 1+captan | 76.3 | 79.0 |
| 1, Em. | 70.8 | 74.8 |

[a] Wettable powder, except emulsifiable (Em.) as indicated.
[b] Each figure represents the mean of 4 replications of 100 seeds each.
[c] Captan was used in all fungicide treatments at the rate of 1 ounce of 75% material per bushel of seed.

**Table 4.—Greenhouse tests with Blackhawk soybeans treated with lindane and captan in various combinations and planted at 6-week intervals in sand to study the effects on seedlings. 1954.**

| Length of Storage (Weeks) | Type of Measurement | Treatment[a] | | | |
|---|---|---|---|---|---|
| | | Control | Captan | Lindane + Captan | Lindane |
| Freshly treated | Mean final emergence | 23.8 | 22.4 | 22.8 | 23.2 |
| | Mean green weight (gm.) | 1.7 | 1.7 | 1.7 | 1.7 |
| | Total seed coats remaining | 0 | 0 | 0 | 0 |
| 6 | Mean final emergence | 20.2 | 19.0 | 19.8 | 19.0 |
| | Mean green weight (gm.) | 1.7 | 1.8 | 1.7 | 1.7 |
| | Total seed coats remaining | 0 | 0 | 0 | 0 |
| 12 | Mean final emergence | 18.6 | 17.8 | 17.2 | 16.2 |
| | Mean green weight (gm.) | 1.3 | 1.2 | 1.1 | 1.2 |
| | Total seed coats remaining | 0 | 0 | 0 | 0 |
| 18 | Mean final emergence | 24.0 | 25.0 | 24.6 | 23.8 |
| | Mean green weight (gm.) | 1.8 | 1.7 | 1.5 | 1.5 |
| | Total seed coats remaining | 0 | 1 | 15 | 2 |
| 24 | Mean final emergence | 24.0 | 22.6 | 23.6 | 24.2 |
| | Mean green weight (gm.) | 1.7 | 1.5 | 1.5 | 1.6 |
| | Total seed coats remaining | 1 | 49 | 77 | 8 |
| | Number dead seedlings[b] | 1 | 3 | 28 | 2 |
| Freshly treated for comparison with 24 weeks | Mean final emergence | 23.8 | 24.0 | 23.6 | 24.4 |
| | Mean green weight (gm.) | 1.8 | 1.5 | 1.5 | 1.6 |
| | Total seed coats remaining | 0 | 63 | 81 | 2 |
| | Number dead seedlings | 0 | 3 | 22 | 0 |

[a] Each value represents the mean of 5 replications of 25 seeds each.
[b] No dead seedlings were noticed in the first 4 tests.

The test planted 12 weeks after treatment was unintentionally subjected to excessive greenhouse temperatures but all treatments were apparently adversely affected to about the same extent. Subsequent tests were moved to a screenhouse where excessive temperatures were not reached.

The figures for the mean green weights show that seedling injury from chemical treatments appeared after about 12 weeks of storage, and was even more pronounced in later tests. The values for the chemical treatments were significantly lower than those of the control. There was no important difference in mean green weight among the chemical treatments. The figures for the lindane plus captan treatment would have been even lower if the diseased seedlings had not been omitted from these weighings. These abnormal seedlings, confined largely to the combination treatment, emerged satisfactorily but were darkened and dead at the time the plants were "harvested." They were, however, included in the final emergence data.

Seed coat adherence was found mainly in the two captan treatments. The combination of lindane with the fungicide increased this peculiarity in the last three tests after storage. Little difference was shown by any of the measurements for the storage treatments planted 24 weeks after treatment and the fresh treatments planted the next day. This indicated that under the conditions of this test the injury caused by the chemicals was due mainly to a reduction in seed viability, rather than by prolonged contact of the toxicants with the seed.

The seed used in this experiment was old and the storage temperature differed somewhat from that of commercial granaries. Perhaps captan, especially in combination with lindane, should not be used at a high dosage on soybeans held over a second year before planting. Conversely, captan used on soybeans of high viability may sometimes result in increased stands, as will be shown later.

*Inoculation compatibility with insecticides.*—The inoculation of soybeans with *Rhizobium leguminosarum* Frank has become a widely accepted practice. It is therefore desirable that any insecticide applied to the seed be compatible with this inoculant. A hand-planted experiment of six replications was planted on June 17, 1953, in the insectary garden to study insecticide-inoculant compatibility. This plot had not been planted to soybeans for at least 4 years and thus the supply of nitrogen fixing bacteria present in the soil should have been low. Toxaphene, dieldrin, lindane and heptachlor were slurried on samples of Lincoln soybeans of high viability at the rate of 2 ounces of actual insecticide per bushel. Each of the insecticides was used both with and without inoculant, along with inoculated and non-inoculated controls. Where inoculant was used it was applied in excess just before planting.

The plot size was 2 by 5 hills. The hills were spaced so that the closest distance between hills was 2 feet, in order to largely eliminate competition among plants. Soon after emergence the seedlings were thinned to two of the most vigorous plants per hill. The remaining plants were cultivated and allowed to reach maturity.

On October 3 to 5, the plots were hand threshed, and yields were determined after adjusting all field weights to the same moisture level. The first and second, third and fourth, and fifth and sixth replications, respectively, were combined to give three composited replications of each treatment. From each of these composite samples a 100-gram subsample was analyzed for the percentage of oil and iodine number of the oil.[3] The iodine number was determined by the refractometric method (Hunt *et al.* 1951), and the oil content was derived by the dielectric procedure (Hunt *et al.* 1952), after all subsamples had been dried to 8% moisture. The results of this experiment are given in table 5.

**Table 5.—Results from an insecticide-inoculant experiment grown in the insectary garden at Ames. 1953.[a]**

| Treatment | Mean Yield (Gm.) | Mean Oil Content (%) | Mean Iodine Number (Wijs) |
|---|---|---|---|
| No inoculation: | | | |
| Control | 423.2 | 21.3 | 125.7 |
| Lindane | 427.8 | 20.6 | 128.3 |
| Dieldrin | 422.7 | 21.3 | 127.0 |
| Toxaphene | 435.1 | 21.2 | 127.0 |
| Heptachlor | 466.0 | 21.3 | 126.7 |
| Inoculation: | | | |
| Control | 448.9 | 21.1 | 125.0 |
| Lindane | 493.4 | 21.6 | 125.0 |
| Dieldrin | 464.8 | 21.1 | 126.0 |
| Toxaphene | 425.0 | 21.1 | 126.3 |
| Heptachlor | 476.2 | 21.4 | 126.7 |

[a] Each value represents the mean of 6 replications of 20 plants each.

There was considerable variation in the yields from the plots. However, the inoculated treatments showed significant yield increases when compared as a group with the non-inoculated treatments. There were no significant differences among treatments nor between the insecticide treatments and the control. In the oil content analyses none of the comparisons showed significant differences.

Inoculation lowered the iodine number significantly at the 1% level. Also the controls gave readings significantly lower than those from the insecticide treatments. Furthermore, the effects of the chemical treatments and the inoculations were not independent. The study of interaction showed that most of the heterogeneity could be attributed to lindane, which gave soybeans with oil showing an increased iodine number when this insecticide was used without inoculation. It is of interest to note that the small amount of insecticides used as seed treatments were sufficient to alter the chemical nature of the progeny, as reflected in the change in iodine number. However, more data are needed before final conclusions can be reached.

*Seed-corn maggot control experiments.*—In 1954 field trials were planned to test insecticides at varying levels in relation to seed-corn maggot control. Treatments were slurried on Hawkeye soybeans grown in 1953. A series of 20 treatments involving $\frac{1}{3}$-, $\frac{2}{3}$-, and 1-ounce levels of lindane, heptachlor, or Diazinon, respectively, both with

[3] These determinations were made by the United States Department of Agriculture Production and Marketing Administration Grain Branch, Minneapolis, Minnesota.

and without captan, was used with appropriate controls. This series was planted on the college experimental farms at Cresco and Independence, and in the insectary garden at Ames. At all locations, four replications were included in a split-plot design with the fungicide levels assigned to the whole-plot and the insecticides and their levels to the sub-plot. There were 200 seeds in a 20-foot row at Cresco and Ames, and 100 seeds in a 10-foot row at Independence. Spacing between rows was 40 inches at Cresco and Independence, and 30 inches at Ames. Planting was by hand at Independence on May 13, and at Ames on May 21. For the Cresco planting on May 19 a Columbia III garden planter was used.

In these plantings, fish meal was used with the hope of attracting gravid female flies and enticing them to oviposit in the plots. The fish meal was allowed to soak overnight in water before it was applied at the rate of appoximately ¼ pound per 10 feet of row length. At Ames the fish meal was sprinkled over the top of each row and the plots were watered daily with a garden hose. At Independence the attractant was placed in the row before the seeds were covered with soil, and at Cresco it was placed on the soil surface. It was not feasible to keep the plots watered at either of the latter locations. A summary of stand counts in this experiment is given in table 6.

**Table 6.—Stand counts from chemically treated Hawkeye soybeans planted at three field locations. 1954.**

| Treatment (Ounces) | Mean Stand Count[a] | | |
|---|---|---|---|
| | Ames | Independence | Cresco |
| No fungicide: | | | |
| Control | 170.8 | 30.3 | 151.8 |
| Lindane | | | |
| ⅓ | 168.3 | 41.0 | 165.8 |
| ⅔ | 177.3 | 57.0 | 159.8 |
| 1 | 172.8 | 45.8 | 161.8 |
| Heptachlor | | | |
| ⅓ | 177.0 | 45.5 | 157.5 |
| ⅔ | 176.8 | 46.8 | 154.8 |
| 1 | 169.0 | 50.5 | 157.8 |
| Diazinon | | | |
| ⅓ | 162.3 | 43.0 | 146.0 |
| ⅔ | 159.5 | 41.0 | 147.5 |
| 1 | 150.0 | 43.3 | 154.5 |
| Captan: | | | |
| Control | 174.8 | 29.8 | 159.5 |
| Lindane | | | |
| ⅓ | 172.3 | 52.3 | 164.5 |
| ⅔ | 181.0 | 46.5 | 161.5 |
| 1 | 185.5 | 44.3 | 160.0 |
| Heptachlor | | | |
| ⅓ | 170.3 | 47.3 | 162.3 |
| ⅔ | 179.3 | 49.8 | 158.5 |
| 1 | 187.5 | 48.5 | 149.8 |
| Diazinon | | | |
| ⅓ | 175.0 | 38.5 | 143.3 |
| ⅔ | 178.3 | 44.8 | 155.3 |
| 1 | 179.3 | 51.5 | 159.8 |

[a] Each value represents the mean of four replications. There were 100 seeds per row at Independence, and 200 per row at the other locations.

Independence was the only location where maggots caused noticeable damage. The soil type at Cresco was such that a good seed bed was difficult to prepare, and consequently seedling emergence was so irregular that the results did not allow satisfactory conclusions.

At Ames the fungicide treatments as a group gave increased stands when compared with the no fungicide treatments. The study of interaction showed that the 1-ounce levels of heptachlor and lindane without the combination of captan had appreciably reduced stands, but the main discrepancy was associated with Diazinon which caused a progressive reduction in stand as the insecticide dosage was increased. The addition of the fungicide to these treatments, however, resulted in stand counts from all Diazinon levels comparable to those of the control.

At Independence the plots planted with insecticide-treated seed had significantly higher stand counts than the control rows, presumably because of seed-corn maggot control. There was no large difference in the performances of the 3 insecticides at any of the 3 levels. The addition of captan failed to significantly influence seedling emergence in this test. Over the entire plot emergence was only about 45 per cent. It is possible that the fish meal in the rows interferred with germination in some way.

In review, Diazinon at Ames without a fungicide appeared to reduce stands. At Independence this injury was not pronounced, possibly because the protection against maggots afforded by this insecticide was sufficient to overshadow any phytotoxic effects.

Summary.—Five widely grown varieties of soybeans (Blackhawk, Hawkeye, Adams, Lincoln and Clark) showed no important differences in response to high dosages of BHC, since none of the varieties had large reductions in total emergence or mean green weight under greenhouse conditions.

In field tests soybeans of high viability were not appreciably injured by emulsions of Diazinon, recrystallized aldrin, heptachlor, dieldrin and lindane, and only slightly injured by 2-ounce dosages of the same insecticides used in wettable powder formulations. However, lower dosages of some of these same insecticides severely damaged seed that had been stored for about 19 months before being tested.

Soybeans of an old seed lot treated with captan and germinated in sand were stunted in growth and commonly had their seed coats adhering to the cotyledons after they had been sloughed off in the control. The combination of lindane with the fungicide somewhat increased seed coat adherence. Injury was mainly due to a reduction in seed viability and not by prolonged contact of the chemicals with the seed, since it occurred as readily with freshly treated seed from a standard lot as it did with seed from the same source treated and stored for 6 months.

All the insecticides tested were compatible with captan, and in one field test the fungicide not only increased emergence but also showed some indication of lessening seedling injury caused by 1-ounce dosages of insecticides, particularly Diazinon.

Four insecticides (heptachlor, toxaphene, lindane, and dieldrin) appeared to be compatible with soybean bac-

terial inoculant on the basis of yields. The insecticides as a group were responsible, either directly or indirectly, for a small but significant (at 5 per cent level) increase in the iodine number of the soybean oil. Lindane without inoculant was mainly responsible for the increase. The insecticide treatment presumably influenced the percentage of oil of the progeny very little.

Diazinon, lindane, and heptachlor used as seed treatments gave increases in stands in a plot where flies of the seed-corn maggot were attracted by an application of moistened fish meal. No difference of importance was detected in the protection afforded by ½-, ¾-, and 1-ounce dosages of the insecticides, either alone or in combination with captan.

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# Alfalfa Pollination in Manitoba[1]

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In the development of the alfalfa seed industry in Manitoba, the sequence of events in all of the past and present seed-producing areas has been strikingly similar: (1) high yields and low acreage, (2) moderate yields and moderate acreage, (3) low yields and high acreage, and (4) the inevitable change from alfalfa to another cash crop. The factors causing this sequence have been under scrutiny for a number of years. The many workers in Canada and the United States studying these factors have arrived at many interpretations, some of them contradictory. Such contradictions indicate that separate investigations should be made in each of the ecologically distinct, seed-producing areas. A multitude of conditions are believed to be associated with the seed yield reduction, among them soil, moisture, humidity, temperature, injurious insects, pollinators, diseases, and cropping methods. Undoubtedly all of these factors play an important role in seed production, but each has a different degree of importance in each seed-producing area. For example, in Manitoba conditions are not at all comparable with those in Alberta, Utah, Kansas, or California. Hence, the recommendations of one area may not be necessarily applicable to another.

This paper presents an account of alfalfa pollination studies carried on in Manitoba from 1947 to 1953, with particular emphasis on the habits of the principal pollinating species.

HISTORY OF SEED PRODUCTION.—The history of a typical Manitoba alfalfa seed-producing region is as follows. The first settler enters the new area to start a small, diversified farm, intent on breaking minimal quantities of land during the first few years, but equally intent upon having a small cash crop and seed for the following year. Invariably the first land to be broken has been burnt over and requires the least amount of labor in clearing. In Manitoba alfalfa for forage and seed are always among the first crops used on new land. The yields on these small seed patches are usually exceptionally large. Soon the acreage devoted to alfalfa is increased. A brief period of land expansion follows in which the remaining burnt-over acreages are cleared, refuse is burnt, and the soil is cultivated thoroughly. Within 4 to 10 years, depending upon the intensity of breaking and the influx of new settlers, yields drop from 1000 pounds to 150 pounds or so and alfalfa seed production is no longer profitable.

Thus far, seed growers have been able to compensate for the destruction of the endemic bee habitat by extending the frontiers into new productive hinterlands, but these new lands are rapidly disappearing. If the alfalfa seed industry is to be maintained as a part of Manitoba agriculture, concerted efforts must be directed to the management of suitable areas expressly for legume seed production.

DESTRUCTIVE INSECTS.—A factor of wide variability is the incidence of destructive insects in alfalfa fields. As can be expected, the most abundant pests, their damage, their life histories, and their control vary greatly from Manitoba to California.

As a result of five yearly surveys in Manitoba, pollination appears to be a more important factor in seed production than insect pests. Though mirids and other pests cause some damage they do not now constitute an economic threat to the production of alfalfa seed in Manitoba. They are present in all major alfalfa-growing areas, but their populations have not reached economic significance; fields yielding 40 pounds per acre and others yielding 900 pounds per acre had identical bug counts during the 5 years of the survey. The highest count per sweep of *Adelphocoris* and *Lygus* was 1.8, in the Gimli area. Plot control of thrips and aphids has indicated that

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none of these insects are present in sufficient numbers to warrant control.

TRIPPING STUDIES.—In the past the stripped racemes of alfalfa were ascribed to mirid damage only. Though there may be bud blasting by mirids, this damage probably does not exceed 5 per cent of the total blossom-drop in Manitoba. Non-fertilization or non-tripping of the alfalfa flowers is undoubtedly the major cause of the poor seed yields throughout the Province. In Minnesota Hughes (1943) found 35 per cent of the florets dropping from alfalfa even though the flowers were tripped, cross-pollinated, and caged free from insects. In 1951 similar results were obtained in Manitoba, when the florets on 10 heads were artificially tripped, crossed, and bagged. Of the 281 florets so treated, 33 per cent dropped. This natural drop is indistinguishable from mirid damage in the lattter part of the season and in many cases both have been considered as bug damage.

A test was carried out in 1948 to determine the extent of self-tripping under Manitoba conditions. Racemes were enclosed in plastic bags from a very early stage until all bloom had ended. By this time the bagged racemes showed a marked difference from other racemes in the field. Of the 229 florets on the 10 racemes, only 8 had formed seed pods, with a total of 14 seeds, and this set was ascribed to self-tripping. This difference was striking, for the average unbagged raceme bore 15 pods. The ability of the flowers to self-trip cannot be ignored as a possible factor in seed setting. Hughes (1943) found that 5.4 per cent of the flowers were self-tripped in tests run at St. Paul in 1941. This is slightly higher (5.4 as compared to 3.5) than results obtained under Manitoba conditions, but this figure would undoubtedly vary from season to season and place to place and for different strains and varieties of alfalfa.

HONEY BEES.—Probably the greatest disagreement has centered about the usefulness of the honey bee in tripping and fertilizing alfalfa. Most workers in Utah, California, and Arizona have attributed substantial increases of alfalfa seed to the activities of the honey bee. In other regions the honey bee has been found to be of little or no benefit. In regions in North America where honey bees are used to the best advantage, alfalfa is grown in arid areas under irrigation. Under such conditions where alfalfa is the only plant producing profuse bloom, sufficient pollen and nectar are gathered to result in a seed crop. Conditions somewhat similar can be reproduced in non-arid areas, as has been shown by Olson (1945) and Braun (1949). Observations reveal that when a colony is introduced into a cage that the acquisition of pollen falls off sharply and as a result colony strength dwindles. A lack of pollen for brood rearing eventually results and, in order to maintain the life of the colony, some pollen and nectar are gathered from the only available source. However as soon as the cage is removed the bees revert to other sources for their pollen. Under Manitoba conditions it is impossible to remove the abundant native bloom common in all areas and this negates the value of honey bees. Mr. P. Pankiw (personal communication), now of Canada Experimental Station, Beaverlodge, Alta., has run several field trials in Saskatchewan, using honey bees on alfalfa isolated by large acreages of grain. His preliminary results with 5 colonies per acre gave honey production at −21 pounds and 14 pounds per season, indicating that the nectar supplies available in these areas were insufficient to meet the demands of the introduced population. In the two plots where 5 colonies per acre were used, the seed yields were 142 and 160 pounds per acre as compared with 10 pounds on the checks. Neither of these yields would be profitable. However, the season was retarded and it is possible that greater yields would have been realized under more favorable climatic conditions.

The action of honey bees on alfalfa was observed by the writer when a grower in the Sprague area of southeastern Manitoba introduced 14 colonies of bees into a 10-year-old 4-acre field. In spite of the introduction of the honey bees, the megachilid population in the field was greater at all periods throughout the day (2.6 megachilids to 2.3 honey bees per square yard). The low honey bee population on alfalfa was attributed to a profuse growth of fireweed, alsike clover, white Dutch clover, and sweet-clover in the area. Observations were made on the activities of the honey bee on 3 successive days, and, of the 1000 visits recorded, only 6 florets were tripped. Two of the tripped florets resulted from leg actions in which the hind legs rested on the keel. The other four were tripped while the bee inserted its mouth parts near the bases of the florets. None of the bees was observed to approach the floret directly. The field yielded 1000 pounds per acre, but it is doubtful whether the additional 100 pounds over the previous year can be attributed to the activities of the honey bees.

A second field, of 5 acres, was kept under observation during the same year. This field was in the interlake area of Manitoba, a habitually poor alfalfa seed producing region. Fifteen colonies of honey bees were placed alongside the field, which was surrounded by a semi-mature, poplar-oak sub-climax. Unlike the southeast, where alfalfa is grown in small patches surrounded by an old burn of poplar-spruce forest, the vegetation of this area is very dense, with no burn and few open patches. A check field of 4 acres, 3 miles to the east, was kept under observation. Comparable population counts of honey bees and native wild bees were made on 2 successive days on the two fields. The numbers of leaf-cutter bees ranged from 0.0 to 1.00 (average of 0.02) per square yard and of the bumble bees from 0 to 2 (average of 0.55) per square yard on the basis of counts on 40 areas 1 yard square. Honey bee counts on the overpopulated field averaged 3.62 per square yard and on the check 1.09. Even with this difference in populations the check field yielded 63 pounds per acre and the one with more honey bees, 65. In 400 honey bee visits observed, one floret was tripped, and this accidentally while the bee entered from the side. None of the honey bees was observed to gather pollen from the alfalfa.

Mr. John Geiger (in litt.), apiarist at the Canada Experimental Farm in Brandon, recorded visits of honey bees to 10,000 alfalfa florets and of these only four were tripped. It therefore appears that honey bees are of little importance in alfalfa seed production in Manitoba, probably because of the abundance of sources from which pollen can be more readily obtained. Honey bees are not to be discounted as alfalfa pollinators but the regions in which they can be successfully employed are limited.

It should be noted that in the thousands of honey bees observed in the field and the numerous pollen samples collected by means of traps, that no alfalfa pollen collecting honey bees have been seen. The tripping that has been noted was done accidentally by nectar collecting bees. These data are very similar to those recorded by Hobbs (1950) in Alberta where he estimates that less that 0.81% of florets visited by honey bees are tripped. Table 1 gives comparative data of honey bee tripping efficiency in various regions of North America.

The effectiveness of nectar collecting honey bees in cross-pollinating florets that they have tripped has been questioned. If the florets are self-pollinated, then honey bees may be more of a detriment than an asset. The work of Pharis & Unrau (1953) contributes something to this problem. Their observations showed that artificially crossed florets produced an average of 4.7 seeds per pod, those tripped by honey bees produced 3.7, and those tripped by leaf-cutter and bumble bees yielded 4.5. Seven of the 12 florets tripped by honey bees produced 26 seeds and 23 of these seeds were in pods on a single raceme (this does not correspond to their tabular data, which indicate that 3 of the pods yielded 21 seeds, 1 pod yielded 2 seeds, and 3 pods yielded 1 seed each). Thus their average of 3.7 seeds per pod was made on the basis of 21 seeds in 3 pods and 5 seeds from 4 pods. Two interpretations can be drawn from these data. First, the average of 3.7 seeds per pod suggests that cross-pollination occurred at the time of tripping by the honey bee. However, when all of the data are considered, only 3 of the 7 tripped florets appear to have been crossed and the other 4 selfed. As the three crossed were found on one raceme it is possible that the plant may have been highly self-tripping and self-fertile, as suggested by the authors. If this is so, then it appears that honey bee tripping results in selfed rather than crossed florets. The only conclusion to be drawn from this is that insufficient data have been gathered on this phase of the problem and further investigation is necessary before the value of the honey bee can be assessed.

MEGACHILE SPP.—Undoubtedly the most efficient pollinators of alfalfa in Manitoba are some of the species of the genus *Megachile*. They approach the floret directly, move from raceme to raceme, and usually collect pollen. Within the genus there are several species that are efficient, both in their speed of visitation and their ability to trip the flowers. The intervals during which observations were made ranged from 20 to 186 seconds and it was usually possible to observe the more efficient species for at least 30 seconds. Table 2 gives the results of observations made on the six principal species of *Megachile* found in Manitoba during the years 1947, 1948, and 1951. A marked difference exists in the ability of the different species to trip the alfalfa floret.

The observations on bee activity were made in the following manner. An area 1 yard square was marked out before the plot was to be observed. The plot was approached in such a manner that the investigators was downwind from it, taking care not to cast a shadow across it at any time. After 2 minutes, which allowed any disturbed bees to settle, the numbers of bees were recorded. Bee counts were then taken at the beginning and at the close of a 1-minute observation period and these counts averaged. Tripping ability of the bee was recorded by following a specimen through the field and catching it for determination just when it appeared to be about to make a long flight.

*M. frigida* Smith and *M. latimanus* Say are exceptionally efficient and show a preference for alfalfa even when there is abundant clover, fireweed, or other wild bloom adjacent to it. Examination of the competing flora in the area failed to yield either of the two species, in spite of their abundance on nearby alfalfa. Inconsistent results were obtained for several of the other species listed (Table

Table 1.—Alfalfa tripping efficiency of honey bees in several North American areas.[a]

| LOCATION | NECTAR COLLECTORS | POLLEN COLLECTORS |
|---|---|---|
| Kansas (Grandfield & Franklin 1952) | 1.1 | 65 |
| Utah (Vansell & Todd 1946) | 17.5 | 59 |
| California (Vansell—personal communication 1954) | 2–10 | 50–99 |
| Washington (Menke 1954) | 0.4 | not seen |
| Alberta (Hobbs 1950) | 0.81 | not seen |
| Manitoba | 0.10 | not seen |

[a] All figures in per cent trip of flowers visited.

Table 2.—Observations on *Megachile* activity on alfalfa in 1947, 1948, and 1951 in southeastern Manitoba.

| SPECIES | YEAR | NUMBER OBSERVED | FLORETS VISITED | PERCENTAGE TRIPPED |
|---|---|---|---|---|
| *frigida* Sm. | 1947 | 21 | 481 | 97.3 |
| | 1948 | 12 | 103 | 98.1 |
| | 1951 | 14 | 264 | 98.8 |
| Total | | 47 | 848 | 97.5 |
| *latimanus* Say | 1947 | 9 | 156 | 96.1 |
| | 1948 | 4 | 38 | 86.8 |
| | 1951 | 11 | 168 | 97.0 |
| Total | | 24 | 362 | 95.6 |
| *brevis* Say | 1947 | 3 | 14 | 14.3 |
| | 1948 | — | — | — |
| | 1951 | 2 | 6 | 16.6 |
| Total | | 5 | 20 | 15.0 |
| *relativa* Cress. | 1947 | 2 | 8 | 25.0 |
| | 1948 | 2 | 14 | 42.8 |
| | 1951 | 2 | 14 | 64.3 |
| Total | | 6 | 36 | 47.2 |
| *melanophaea* Sm. | 1947 | 4 | 23 | 60.9 |
| | 1948 | 1 | 8 | 0.0 |
| | 1951 | 3 | 17 | 52.9 |
| Total | | 8 | 48 | 47.9 |
| *inermis* Prov. | 1947 | 1 | 5 | 20.0 |
| | 1948 | 3 | 33 | 48.5 |
| | 1951 | 1 | 6 | 0.0 |
| Total | | 5 | 44 | 38.6 |

1). For example, during 1947 *M. melanophaea* Smith tripped 60.9 per cent of the flowers visited, but in 1948 the same species tripped none of the florets on which it was seen. The observations on this species were made in two fields of alfalfa in the Sprague area of Manitoba. Field 1 was surrounded by large tracts of 14-year-old burnt-out poplar in which there was abundant competing bloom, whereas Field 2 was in the midst of a live poplar-spruce succession nearing the spruce climax. About the edge of the latter field there was a good supply of dead timber and some open land.

In the areas where fireweed and volunteer clovers were scarce, *M. melanophaea*, *M. relativa* Cresson, *M. inermis* Provancher, and *M. brevis* Say were all observed to trip a good percentage of the florets visited, but in a situation where competing bloom was abundant (Field 1) these species were of little benefit (Table 2).

The observations made on the two fields were done in a similar manner, but in spite of their proximity the bee species populations were not numerically comparable. Field 1, 4 acres, was 12 years old and surrounded by vast areas of burnt-out poplar. The alfalfa had not been cultivated since its planting, and as a result the periphery of the field served admirably for the soil-nesting species, e.g., *M. latimanus*. Because of the vast virgin area about Field 1, populations of the leaf-cutter bee were high. There were 2.6 megachilids per square yard on a basis of hourly observations taken on 2 consecutive days in 1948, with the average activity temperature ranging between 80 and 90 degrees. Seed yields on this plot in 1947 amounted to 850 pounds per acre and in 1948 to 1200 pounds. However, such yields are not common; 400 to 500 pounds would be nearer to the district average.

Field 2, 8 acres, and 4 years old, yielded 600 pounds in 1947 and 700 pounds in 1948. The leaf-cutter bee population was low on this plot (0.5 per 2 square yards), but *Bombus* populations were invariably higher than on Field 1.

The apparent intraspecific tripping efficiency of *M. brevis* in various sections of the United States and Canada warrants some speculation as to its cause. Grandfield & Franklin (1951) report that *M. brevis* and *M. texana* Cresson trip 98 per cent of all bloom visited while Linsely & MacSwain (1947) record *brevis* as tripping an average of 16 florets per minute. In Manitoba approximately 5 per cent of the total recorded population was noted on alfalfa, the majority working yellow sweet clover, *Melilotus officinalis*. Bohart (1954) intimates, with honey bees, that tripping efficiency may be affected by a combination of climatic effect on flower "trippability," plant condition and strength of competing bloom, and it is expected that these same conditions would affect the actions of wild bees. Those specimens of *brevis* noted on alfalfa worked the florets much like the honey bees, slipping their mouthparts into the base of the floret between the standard and the keel petals. Only one specimen was observed to be carrying pollen and it approached the floret directly tripping two of the three florets visited. The fact that self-tripping of florets was high and that honey bees had little difficulty tripping alfalfa under cage conditions leads me to believe that the presence of more favorable bloom, rather than alfalfa being harder to trip, was the main cause of plant visitation and tripping efficiency differences in Manitoba.

One of the most striking features of areas harboring large numbers of *Megachile* spp. in Manitoba is the proximity of alfalfa to burnt-over poplar plots and uncultivated land. Continued examination revealed that many long-nesting species of the genus i.e., *frigida* and *inermis*, prefer poplar left after a fire or poplar waste left after logging to any other wood. The bee does not utilize the poplar until the trees have decayed sufficiently to permit the bee to burrow into it. This state is reached from the fourth to the seventh year after felling, and such logs serve as suitable nesting sites until they have decayed to an extent that they offer no protection from the elements. The length of time that poplar remains in use by the bees varies with the size of the log and the rapidity of decay, logs having passed their utilizable stage from 14 to 19 years after felling. Apparently the favorable period for log utilization by bees rarely lasts for more than 20 years, which can be considered as an unstable condition through a period of rapid plant succession. Hence, merely limiting the crop to small, scattered fields would not create an indefinite period of high bee population and high yields. The surrounding forest must be managed and kept in a condition favorable for the bees. *Megachile* spp. observed did not fly over large tracts of forested land to obtain food, but rather constructed their nests in close proximity to the source. Thus the nests are always most abundant where a suitable habitat and food plants exist side by side.

Observations of 843 nests of *Megachile* spp. in various stages of construction showed without exception that the bees remove sawdust in quantity. The position of the nests of the principal log-inhabiting species, *inermis* and *frigida*, indicated that they do not follow borer tunnels. Such nests parallel the outer surface of the tree and are usually straight or weakly curved. The tunnels of the nests of eight specimens of *frigida* and six of *inermis* were begun by the bees at a crack or crevice or at the exposed end of a poplar log.

Possibly the emergence holes of the borers may be used to gain access to the interior of the tree where the outer surface is still too firm, but even then the tunnel is probably followed for not more than $\frac{1}{2}$ inch. Several logs, free of borer holes, were set in the open alongside alfalfa; 6 weeks later these logs contained five *Megachile* tunnels. Two of the tunnels were begun in the partially decayed area about knot holes and the other three were in the open ends of the logs. Exposing the tunnel during construction and covering it with glass allowed *inermis* to be observed excavating. The exposure to sunlight did not affect activity after the initial shock; this species excavated rapidly for $1\frac{1}{4}$ inches during the time of observation.

*Megachile* spp. will nest in a variety of sites. *M. frigida* nests, while most abundant in decaying poplar, were found in straw-stack bottoms, old sawdust from mill waste, in $\frac{1}{4}$-inch brass pipe, and in decayed spruce. McMahon (1953) reports similar or greater variation in nesting sites in Saskatchewan. The good yields still found in some sections of Manitoba are attributable to high populations of wild bees, particularly *Megachile* spp., which find ideal nesting sites in the dead timber and open virgin land of the surrounding uncultivated areas.

The concentration of nests of the leaf-cutter bees may pose a problem of increased parasitism by *Coelioxys* spp., the main parasite of *Megachile* spp. in Manitoba. How-

ever, concentrations of *Megachile* spp., in the southeast portion of the Province have not been so affected. During the 4 years of observation in this area, *Coelioxys* spp., though present in small numbers, did not fluctuate from year to year and did not appear to be the limiting factor in *Megachile* abundance.

In creating conditions favorable for *Megachile* spp. an attempt was made to determine optimum numbers of this bee necessary for adequate pollination. It is difficult to set a numerical constant because of the variability in tripping exhibited by the different species; however, the following calculations were made on the basis of information gathered in comparable faunistic and floristic areas. Such calculations are based on suppositions but do serve as an objective. Observations were made on Field 1 in southeastern Manitoba, where *frigida* and *latimanus* formed 94.3 per cent of *Megachile* spp. found on alfalfa. The field was 12 years old and patchy, but the seed set, attributed primarily to the 2.6 specimens of *Megachile* spp. per square yard, was 1200 pounds per acre. Considering this as near maximum yielded for such a plot, the following computations were made:

2.6 bees per square yard each trip an average of 20 florets per minute, or 18,720 florets per square yard per day (on the basis of a 6-hour day);

assuming that the bees are able to work 5 full days in each season and that 40% of the blossoms fall even though tripped, there would result a total of 56,160 florets per square yard per season;

assuming further that there are at least 3 seeds per pod and that there are 226,800 seeds in a pound, it is computed that the yield per square yard would be 0.66 pound, or 3194 pounds per acre.

As 3194 pounds of alfalfa is considered to be well beyond the maximum possible yield from 1 acre in this plot, the writer believes that the population of *Megachile* spp. in that area was in excess of that required. Assuming 1200 pounds to be a near maximum on this particular plot, only 37.6 per cent of 2.6 bees, or 0.98 bee with the tripping efficiency of *M. frigida*, would have been required. This does not take into account the increasing number of tripped florets as tripping increases, but serves as an approximation of requirements.

BOMBUS SPP.—As with *Megachile* spp., observations on the effectiveness of the various species of *Bombus* as alfalfa pollinators were made during the peak of bloom. Table 3 gives the results of the observations and illustrates that when speaking of alfalfa pollinators one cannot say that *Bombus* or *Megachile* are effective pollinators but must restrict discussion to the species concerned. The variation between species in the percentage of florets tripped is more striking in *Bombus* than in *Megachile*. It should be noted that in the southeast of Manitoba, where the information was obtained, *Bombus* spp. populations were not as numerous as *Megachile* spp. populations and data were more difficult to obtain.

Bumble bee populations undergo great yearly fluctuations and it has proved foolhardy to predict the following year's population on the basis of numbers observed during one flight period. The primary factor in this fluctuation is as yet undetermined but is probably a result of one or more than three conditions during the most critical period in their development, the spring. It is impossible to ascribe more importance to one factor than the other, for each can be limiting on its own. First, the emerging queens must have a good supply of food with which to start the new colony; without it they would starve. Second, a killing frost shortly after emergence, followed by warm weather, results in the destruction of spring food sources. Thus the young queens that emerged in the midst of profuse bloom would re-emerge to an absence of bloom. Unless a secondary plant breaks bud shortly after the frost, the queens face starvation. Third, *Salix* spp. is the predominant source of spring food for the queens in most regions of Manitoba and is usually found in low, wet areas. The queens prefer to build their new nests near the food supplies. Thus great numbers of nests can be found near willows in the poorly drained sites that are most vulnerable to flooding during heavy spring or summer rains. Probably the last-mentioned factor plays the largest role in limiting bumble bee populations in southern Manitoba, for in many years numerous queens were observed on spring bloom and yet the midsummer populations were negligible. The spring of 1948 may serve as an example. Spring populations of queens on willow were exceptionally large, but at the midsummer survey it was difficult to find them on alfalfa. There were no sharp frosts but there was an abnormal amount of rain, after which the farmers of the area told of standing water on all low-lying areas for a week or more. This may be a coincidence, but there were no other obvious variables to which this drastic reduction could be attributed.

Table 3 does not indicate the yearly variation in populations, but the variation was striking. In 1947 it was a simple matter to observe the species on their preferred host or hosts, and an average of one bee per 2

**Table 3.—Observations on *Bombus* activity on alfalfa in southeastern Manitoba.**

| SPECIES | YEAR | NUMBER OBSERVED | FLORETS VISITED | PERCENTAGE TRIPPED |
|---|---|---|---|---|
| *terricola* Kby. | 1947 | 26 | 364 | 90.1 |
| | 1948 | 11 | 89 | 68.5 |
| | 1951 | 28 | 350 | 89.4 |
| Total | | 65 | 803 | 87.4 |
| *ternarius* Say | 1947 | 11 | 100 | 38.0 |
| | 1948 | 6 | 38 | 5.3 |
| | 1951 | 31 | 251 | 38.2 |
| Total | | 48 | 389 | 35.0 |
| *vagans* Sm. | 1947 | 10 | 0 | 0.0 |
| | 1948 | 8 | 18 | 11.1 |
| | 1951 | 8 | 36 | 2.8 |
| Total | | 26 | 54 | 5.6 |
| *fervidus* (F.) | 1947 | 11 | 68 | 33.8 |
| | 1948 | 2 | 7 | 71.4 |
| | 1951 | 7 | 49 | 53.1 |
| Total | | 20 | 124 | 43.5 |
| *rufocinctus* Cress. | 1947 | 2 | 14 | 14.3 |
| | 1948 | 1 | 6 | 0.0 |
| | 1951 | 5 | 29 | 48.3 |
| Total | | 8 | 49 | 32.6 |

square yards was observed on alfalfa. The following year they were notable by their absence and intense searching was required to make the necessary observations. An average population of one bee per 10 square yards was recorded on alfalfa. However, in 1951 the population was up to one bee per 3 square yards.

*B. terricola* Kby. consistently tripped a high percentage of the alfalfa florets visited and was the only species that preferred alfalfa over red or alsike clover. Several opportunities were taken during 1951 to observe volunteer alfalfa in the midst of a red colver stand and in the midst of abundant volunteer alsike. Of the 1196 bumble bees noted on alfalfa under these circumstances, 1064 were of *terricola*, 65 of *ternarius*, 41 of *rufocinctus*, and 26 of *fervidus*.

Similar observations made during the same year on single plants or small patches of red and alsike clovers in alfalfa fields are recorded in table 4. The information is much more pertinent when it is considered that *terricola* outnumbered all other species by 2.38 to 1.

Of the other five species that are abundant in Manitoba, only *ternarius* showed any inclination to work alfalfa and this in areas where competing bloom was at a minimum. Workers of this species tripped an average of 35 per cent of the florets visited.

The higher percentages of tripped flowers recorded for *fervidus* and *rufocinctus* are a result of visitations made by late-emerging queens early in the blooming season of alfalfa. The queens of these species appear to work all bloom with equal vigor and will move from alfalfa to red clover or to fireweed, collecting pollen from any or all sources. All of the 1951 observations on *fervidus* were made on queens. For the same year, two of the five *rufocinctus* specimens observed on alfalfa were queens and these visited 13 florets, tripping 9.

Several factors that limit the population of bumble bees lend themselves to manipulation but others are not alterable. For example, nothing can be done about the ever-present danger of frost and its effect upon the spring bloom, or about the danger of flooding the low-lying areas where many queens nest. Planting an abundant supply of early-blooming willow on the better-drained upland areas, where alfalfa is sown, may induce the queens to nest in higher ground. An abundant supply of leaf mould and refuse, as well as many rotted stumps in such an area, should serve admirably for nesting sites. A second planting of *Caragana* spp. which blooms after the willow and before the alfalfa, would carry the bees over and keep them working in the general area until alfalfa came to full bloom. Limiting the volunteer alsike clover and fireweed might force workers of all species to work alfalfa for pollen as well as nectar.

**Table 4.—Bumble bee visits to volunteer plants of red and alsike clovers in alfalfa stands, 1951, in southeastern Manitoba.**

| SPECIES | RED CLOVER | ALSIKE CLOVER |
|---|---|---|
| *terricola* | 74 | 63 |
| *ternarius* | 254 | 87 |
| *vagans* | 233 | 91 |
| *fervidus* | 68 | 127 |
| *rufocinctus* | 197 | 132 |

SUMMARY.—The production of alfalfa seed in Manitoba is most successful in the lands adjacent to uncultivated areas. The steady encroachment of agriculture into these semi-isolated areas has resulted in a progressive decrease in seed yields until now but a few of the formerly high-yielding areas are productive. The elimination of the native bee fauna is the main cause for the decline in seed yields. Management practices to maintain an optimum habitat for the principal pollinators are outlined.

Observations on plant preferences and tripping efficiencies of the endemic species of leaf-cutter bees, *Megachile* spp., and bumble bees, *Bombus* spp., indicate that there are marked differences in the abilities of the species of these genera to trip alfalfa florets. Because of these differences it is suggested that the term "wild bees" be supplanted by the species names of the wild bees involved whenever reference is made to the role of these bees in alfalfa pollination.

Honey bees are of little importance in alfalfa seed production in Manitoba, because of the abundance of sources from which pollen can be more readily obtained. Honey bees are not to be discounted as beneficial to alfalfa seed production in general, but the regions in which they can be successfully employed are limited.

The destructive insects on alfalfa do not constitute as serious a threat to the production of seed in Manitoba as they do in other alfalfa areas. Though *Adelphocoris* spp., *Lygus* spp., thrips, and aphids are present, little control is practised or required.

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# Some Effects of Insecticide Seed Treatment on Dent Corn[1,2]

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Insecticide seed treatment of corn to combat wireworms and other seed-attacking insects has been used extensively during recent years, according to Lilly (1954). The present investigation was intended to compare different methods of applying varying dosages of lindane, and to make general observations on phytotoxicity and insect control following the use of this and other insecticides.

Germination tests were carried out in the greenhouse during the winter and spring months of 1952 to 1954, inclusive. Thus it was possible to obtain indications of the performances of most treatments before more laborious tests were undertaken in the field. Hand-planted field experiments were set up at various locations to test the treatments under field conditions. Phytophagous soil insects were not present in conspicuously damaging numbers so that differences in stand could be attributed mainly to direct actions of the treatments. Advantage was taken whenever possible of natural infestations of wireworms in farmers' fields to investigate the value of seed dressings against seed-attacking insects on a large-plot basis. Supplementary laboratory tests were performed with soil insects exposed to treated seed. These laboratory tests were intended to give information on the effective dosage of lindane, and to compare lindane with certain other insecticides.

Materials and Methods.—The seed corn used was from commercial seed lots which had been cleaned and processed with standard mechanical equipment but not treated with a fungicide.[4] The chemicals were commercial formulations, but a diluent, pyrophyllite, was sometimes added to give a specific concentration of insecticide. For greenhouse experiments, and for hand-planted field tests involving small amounts of seed, treating was done in the laboratory. The dosages of insecticides and fungicides were calculated on the basis of ounces of actual ingredients per bushel of seed. A 2½% methyl cellulose solution was used in modified slurry applications of dry formulations. Usually 5 milliliters of this sticker were adequate for 1 pound of seed. In one series of treatments, 10.7 milliliters of acetone per pound of seed were used as a solvent for crystallized lindane. In all other treatments the insecticides were wettable powder formulations, most of which contained 25% of the active ingredient.

The mixing and storage containers in most cases were either quart- or pint-size Mason fruit jars which conveniently held 1 pound and ½ pound of seed, respectively. Mixing was done partly by hand and partly on an electrically-driven rotator. The total mixing time was 5 minutes which included hand shaking of the jars for ½ minute to distribute the sticker, if any had been used, before dry ingredients were added. Whenever a fungicide was combined with an insecticide, the two were thoroughly mixed in a shell vial before being applied to the seed. Dry ingredients were added in two or more portions with an interval of hand shaking of the jars after each addition. Finally the jars were placed on the laboratory mixer and rotated at approximately 56 revolutions per minute. After the mixing was completed the jars were left uncovered over night to permit the dissipation of excess moisture.

The experimental design for all greenhouse tests was a randomized complete block. Washed river sand was usually the germination medium. It was held in either wood or metal flats measuring approximately 3½×14×20 inches. Five rows were planted lengthwise in a random arrangement in each flat. The planting furrows were 1½ inches deep and were made with an improvised planting board. A predetermined number of seeds was planted in each row. Each day the surface of the sand was leveled to facilitate accurate readings of daily seedling emergence. Seedlings were considered as emerged when the coleoptile could be seen above the surface of the sand. The mean emergence period was calculated by the method proposed by Leach & Smith (1945). On the tenth day after the seeds were planted the seedlings in each row were removed from the flats, washed, and weighed. In addition, the lengths of the primary roots were sometimes measured as a further evaluation of treatment effects.

For hand-planted field tests the desired number of seeds for each plot was counted in the laboratory and placed in a coin envelope. In the insectary garden at Ames each plot consisted of a single 20-foot row. The experimental design was a split plot, with insecticide treatments assigned to the sub-plot and fungicide treatments allotted to the whole-plot. The seeds were dropped by hand in a trench made with a garden wheel-hoe and covered with approximately 3 inches of soil firmly tamped down. The spacing between rows was 2 feet. Stand counts were taken after enough time had elapsed to allow emergence of seedlings that would normally contribute to a stand under field conditions.

In all other hand-planted experiments each experimental unit consisted of a two-by-five hill plot with a 40-inch spacing between hills. A randomized complete block design was used throughout. Four apparently undamaged kernels were planted in each hill with a hand planter. One or more border rows were planted around the test blocks and normal cross-cultivation practices were followed during the growing season. Stand counts were taken early in the growing season, and at this time missing hills were replanted with a purple variety of corn in order to maintain plant competition throughout the experiment without contributing directly to the harvested yields.

In the fall the corn in each plot was hand-harvested

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[4] The corn seed was donated by the Pioneer Hybrid Seed Corn Company, Johnston, Iowa.

and weighed. Twenty ears were taken at random from each lot for moisture determinations. Two rows of kernels were shelled from each of these ears with a screw driver, and the sample was thoroughly mixed before a 1-pint subsample was placed in an airtight container. This subsample was allowed to stand over night at room temperature before moisture determinations were made electrolytically on a Tag-Heppenstall meter. The moisture determinations from all replications of a given treatment were averaged and this figure was used to obtain the yields in bushels per acre of shelled corn at 15.5% moisture.

Treating procedures for a large field trial involving cooperation with a farmer were carried out under practical farm conditions. The mixing container was a 10-gallon milk can in which ½ bushel of corn could be treated satisfactorily at one time. Two-thirds cup of methyl cellulose solution was added as a sticker to each lot before the insecticide was sifted over the grain. The can was rolled on the ground until the insecticide and carrier were evenly distributed over the seed.

Wireworms used in laboratory tests were collected from bait traps placed in corn fields during the growing season. Seed-attacking beetles were captured in a light trap equipped with a fluorescent bulb. Insects were provided with food and stored in a cool place until needed.

EXPERIMENTS AND RESULTS.—The data from most of the experiments were analyzed statistically by an analysis of variance. The detailed statistical analyses have been omitted to save space.

*Slurry versus solution method of lindane application.*—The modified slurry method of insecticide application, which uses methyl cellulose as a sticker, was compared with other means of applying the insecticide. In tests comparing the modified slurry method with a method employing acetone as a solvent each method was used with four levels of lindane, all in combination with either thiram or captan to give a total of 25 treatments. Thiram was used at the rate of ⅔ ounce of active material while captan was applied at 1.12 ounces of active material per bushel of seed. The series was applied to two varieties of corn, Pioneer Hybrids 339 and 379. Soon after treatment part of the seed of each lot was transferred to each of 3 friction-lid cans and stored at 32° F., 45° F., and room temperature, respectively, for about 5 months before being planted at 3 field locations. Both hybrids at all three storage temperatures were planted in the insectary garden at Ames on April 26, 1952. There were three replications with 50 seeds hand-planted in each row. Treated seed of both hybrids stored at room temperature was planted at Ankeny in four replications on May 3, 1952. Hybrid 379 from the 45° F. storage temperature was also

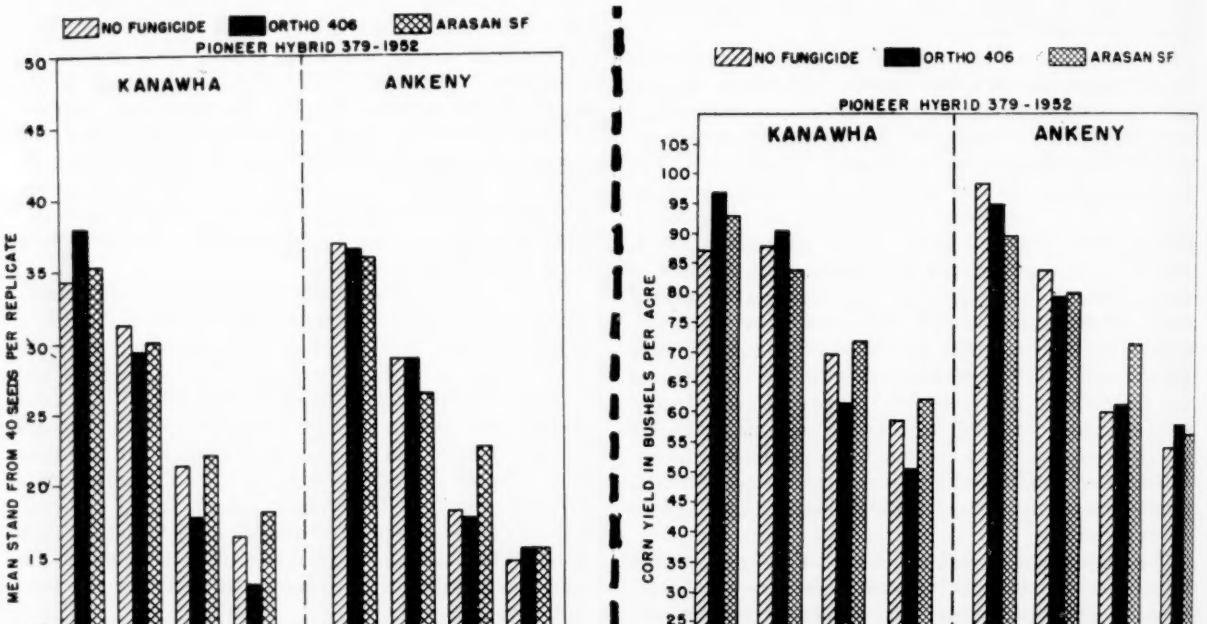


FIG. 1.—Left: Field corn stand counts at two locations where a control and three different levels of lindane were applied to the seed in acetone solutions in the presence of (a) no fungicide, (b) Captan (Ortho 406), and (c) Arasan S.F. Right: Yields from the plantings shown at the left. Both stands and yields decreased as the lindane dosages increased.

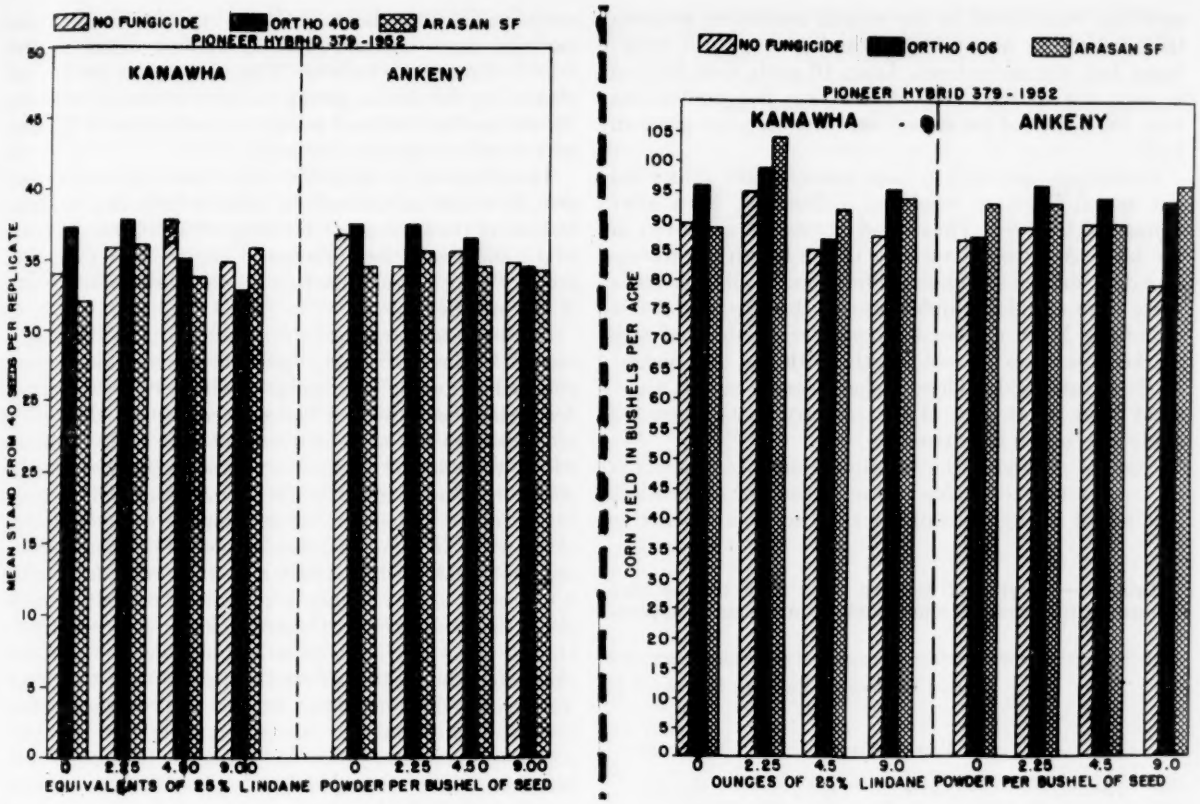
NO FUNGICIDE
ORTHO 406
ARASAN SF
PIONEER HYBRID 379 - 1952
KANAWHA
ANKENY
MEAN STAND FROM 40 SEEDS PER REPLICATE
0 2.25 4.50 9.00
EQUIVALENTS OF 25% LINDANE POWDER PER BUSHEL OF SEED
CORN YIELD IN BUSHELS PER ACRE
0 2.25 4.5 9.0
OUNCES OF 25% LINDANE POWDER PER BUSHEL OF SEED

FIG. 2.—Left: Field corn stand counts at two locations where a control and three different levels of 25 per cent lindane powder were applied to the seed by a modified slurry method with Methocel sticker so as to parallel the treatments shown in fig. 1. Right: Yields from the plantings shown at the left. Note that both stand and yield were about average for the season, even where twice the standard lindane dosage was used.

planted at Kanawha in three replications on May 29, 1952. Total plant emergence was recorded for all three experiments, but yields were not taken at Ames because of the narrow spacing of the rows.

The relationships of the stands and yields of treatments on Hybrid 379 planted at Kanawha and Ankeny are shown in figures 1 and 2. Acetone solution applications progressively reduced both stand and yields as the dosage of lindane was increased. Stand was reduced by more than one-half with the highest level of lindane. Yield was only slightly greater and there was an obvious high positive correlation between yields and stands. Conversely, the methyl cellulose treatments, as shown in the graphs, gave results similar to those of the controls, regardless of the level of lindane. The stand count results at Ames for Hybrid 379 were in close agreement with those at the other two locations.

On Hybrid 339 in the Ankeny planting lindane applied in acetone solution slightly reduced the stand, but this reduction did not cause a corresponding reduction in yield. Although no data are presented, the methyl cellulose method of application on Hybrid 339 gave favorable results, even at double the recommended dosage of lindane at Ankeny. Hybrid 339 was not planted at Kanawha. Neither the presence of a fungicide nor storage temperature had any apparent influence on the stand of either variety as reflected in the stand counts at Ames. None of the treatments on Hybrid 339 was conspicuously phytotoxic at Ames. Because these data are lengthy, none of the results at Ames are given in this paper.

In summary of these experiments, the two corn hybrids differed noticeably in their tolerance of lindane applied with acetone, but neither hybrid was severely injured when methyl cellulose was employed, even at double the recommended dosage of lindane.

*Slurry versus dry method of application.*—A series of treatments was designed to compare the modified slurry and dry methods of applications at different levels of lindane, either with or without captan as a fungicide. For all treatments the bulk of added material placed on the seed was kept constant at $2\frac{1}{3}$ ounces of dry material per bushel by adding an inert pyrophyllite base processed especially for seed treatment. The levels of lindane were 1, $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, and $\frac{1}{16}$ ounce of purified gamma isomer per bushel of seed. Dry and slurry treatments were processed for the same length of time and by the same procedure, except for the omission of liquid from the dry applications. Pioneer Hybrid 349 seed was used. The dosage of captan was 1 ounce of 75% active material per bushel of seed.

The treatments were planted in sand in the greenhouse soon after mixing. There were 2 trials of 4 replications each with 10 kernels planted in each row. Also the treated

seed lots were stored in the mixing containers at room temperature for about 14 months before a third greenhouse test was carried out. Again 10 seeds were planted in each row of the flats but this time five replications were used. Part of the data from these tests are given in table 1.

Emergence data and average green weight values did not reveal large or consistent differences, even after storage of the seed. Thus these figures are not given in the table. Analyses of variance of the length of primary root data showed significant differences. In all three trials there were significant differences in the effects of levels of lindane. Most of these differences were associated with marked decreases in root lengths with the two highest levels of insecticide. These higher dosages caused somewhat more shortening of the primary roots when the seeds were tested after storage.

Another portion of the variation among treatments in all trials was attributable to the method of application. The use of methyl cellulose as a sticker was superior to applying the ingredients as a dry powder in that the modified slurry method reduced seedling injury at the higher dosages of lindane. This may perhaps be explained by the sticker giving an even coverage, whereas the dry method allowed a high concentration of lindane on a sensitive region of the seed.

The action of the fungicide in the three trials was variable. In trial 2 captan had the greatest influence, perhaps because of the presence of damping-off organisms. In both trial 2 and trial 3 the presence of captan gave increased primary root measurements with the three lower levels of the insecticide.

*Do corn seedlings outgrow lindane injury?*—The injury caused by lindane at the time of germination is pronounced and easily demonstrated with corn seedlings under certain conditions. A factor of concern is whether or not seedlings are able to overcome this early stunting when it occurs. A preliminary experiment was set up with corn planted in earthen pots containing soil to study the effects of lindane on the seedlings at different stages of growth. An equal number of pots was planted with seed not treated with lindane and with seed coated with 2 ounces of actual lindane per bushel. Soon after emergence the seedlings were thinned to five in each container. On the sixth day after planting, and every third day thereafter, the seedlings from five pots of each treatment were removed from the soil, washed, and weighed before the primary roots were measured. The test was discontinued after the 18th day because the roots were becoming badly entangled in the pots. Results are presented in table 2.

There are several factors in this experiment which require comment. The test consisted of only the first 5 seedlings to emerge from 8 seeds planted in each container; therefore the lower extremes of germination were not considered. This made the measured differences smaller among plants in a container but also tended to make differences smaller between lindane treatments and the controls, as one or more of the lindane treated seeds were often a day or more late in producing seedlings. Also the use of soil instead of sand as the germination medium decreased the expression of root clubbing by lindane, although a comparatively high dosage of insecticide was used. A larger number of plants would no doubt have been desirable.

Up to and including the ninth day after planting the

**Table 1.—Lengths of primary roots from treated corn comparing the modified slurry and dry methods of application.[a]**

| Treatment (Ounces) | Mean Length of Primary Roots (In.) | | |
|---|---|---|---|
| | Freshly Treated[b] | | Stored 14 Months[c] |
| | Trial 1 | Trial 2 | Trial 3 |
| Dry Treatments: | | | |
| Control | 7.1 | 7.3 | 7.0 |
| Captan control | 6.5 | 9.8 | 7.0 |
| Lindane | | | |
| 1/16 | 8.3 | 8.4 | 6.6 |
| 1/8 | 8.3 | 9.2 | 7.2 |
| 1/4 | 7.2 | 8.2 | 7.5 |
| 1/2 | 5.4 | 5.6 | 3.1 |
| 1 | 3.4 | 3.6 | 2.1 |
| Lindane+captan | | | |
| 1/16 | 7.7 | 10.5 | 7.2 |
| 1/8 | 7.4 | 10.7 | 6.7 |
| 1/4 | 6.7 | 8.1 | 5.9 |
| 1/2 | 4.8 | 5.2 | 3.0 |
| 1 | 3.2 | 4.4 | 2.3 |
| Methyl cellulose treatments: | | | |
| Control | 7.0 | 8.3 | 7.4 |
| Captan control | 7.8 | 9.5 | 7.8 |
| Lindane | | | |
| 1/16 | 6.5 | 9.5 | 6.5 |
| 1/8 | 7.3 | 7.9 | 6.5 |
| 1/4 | 7.3 | 8.5 | 6.7 |
| 1/2 | 6.7 | 6.9 | 5.5 |
| 1 | 5.3 | 5.6 | 2.7 |
| Lindane+captan | | | |
| 1/16 | 7.7 | 10.9 | 6.8 |
| 1/8 | 6.4 | 8.4 | 7.6 |
| 1/4 | 7.8 | 8.2 | 5.6 |
| 1/2 | 8.2 | 7.4 | 3.9 |
| 1 | 4.2 | 5.5 | 2.3 |

[a] Seed germinated in sand soon after treatment and again 14 months after storage at room temperature.
[b] Each value represents the mean of 4 replications of 10 seeds each.
[c] Each value represents the mean of 5 replications of 10 seeds each.

**Table 2.—Comparison of lindane treated corn seed with untreated seed at different stages of growth in soil in the laboratory.**

| Days After Planting | Percentage of Lindane-Treated Seeds of the Control[a] | |
|---|---|---|
| | Mean Green Weight (gm.) | Mean Length of Primary Roots (in.) |
| 6 | 89 | 52 |
| 9 | 90 | 54 |
| 12 | 100 | 82 |
| 15 | 104 | 71 |
| 18 | 99 | 85 |

[a] Each value represents the mean of 5 replications consisting of 5 seedlings each.

lindane treatment had seedlings with appreciably lower average green weights. Sometime after the ninth day the lindane treatments presumably outgrew this difference in seedling weight. The primary root measurements showed that lindane resulted in shortened primary roots. This difference was not overcome during the duration of the experiment, but after the sixth day the primary roots of seedlings of the insecticide treatment increased in length approximately the same amount as did those of the control seedlings. No important difference could be detected in the number of secondary roots present in comparisons of the two treatments.

*Seed-corn maggot field experiment.*—In 1954 a field test was planned to test insecticides and dosages in relation to seed-corn maggot control. A series of treatments involving ⅓-, ⅔-, and 1-ounce levels of lindane, heptachlor, and Diazinon, either with or without captan, was used along with control treatments. Captan was applied at the rate of 1 ounce of 75% material per bushel. Treatments were slurried on Pioneer Hybrid 349 and planted in the insectary garden at Ames on April 24, 1954 in four replications. Each row was planted with 150 seeds of a randomly-selected treatment.

After planting about ½ pound of pre-soaked fish meal was sprinkled over the top of each row in hopes of attracting ovipositing seed-corn maggot females. The fish meal was moistened daily with water from a garden hose except on rainy days. A maggot infestation of sufficient magnitude did not materilize, although conditions appeared to favor maggot establishment. Adult flies were numerous during germination and the soil temperature averaged about 56° F.

Although there were no significant differences among the insecticides at any of the three levels, the experiment was indicative as a fungicide test. Not only was captan compatible with the insecticides but there was a highly significant increase in stand when the captan treatments were compared with no fungicide treatments, even though the design of the experiment de-emphasized this comparison. This increase in stand was not large but it was fairly consistent as shown in table 3.

*Experiment with natural wireworm infestation.*—A field near Centerville, Iowa was in first-year corn following sod in 1952. The farmer treated the seed corn for the original planting with a commercial preparation of lindane, but he used only about ⅔ of the recommended dosage. The resulting stand was so severely reduced by wireworms that replanting was necessary. In the replanting a soil insecticide experiment was carried out, although the seed was treated throughout the field as an added protection. Lindane was applied at a dosage of 4½ ounces of 25% gamma isomer per bushel on Pioneer Hybrid 300-A seed, using a 10-gallon milk can as the mixing container.

The soil treatments were applied on May 8, 1952. Emulsifiable concentrates of BHC, chlordane, and aldrin were diluted with water to give 2 pounds of actual material, and applied separately to the soil surface by means of a tractor-mounted sprayer. Plots were 12 or more rows wide to minimize overlapping of treatments due to drift and cultivation. An unsprayed area was left in each replicate as a control. The entire field was disked soon after spraying to mix the insecticides into the soil and to destroy the remaining seedlings from the previous planting. The field was drill planted on May 10, the same day the seed was treated with lindane.

**Table 3.—Stand counts from a seed treatment test having three levels of each of three insecticides, both with and without a fungicide, at Ames, Iowa. 1954.**

| TREATMENT (OZ./BU.) | MEAN NUMBER OF PLANTS[a] |
|---|---|
| No fungicide: | |
| Control | 123.8 |
| Lindane | |
| ⅓ | 118.5 |
| ⅔ | 110.5 |
| 1 | 115.3 |
| Heptachlor | |
| ⅓ | 114.5 |
| ⅔ | 115.8 |
| 1 | 113.5 |
| Diazinon | |
| ⅓ | 119.0 |
| ⅔ | 116.0 |
| 1 | 107.5 |
| Captan treatment: | |
| Control | 131.5 |
| Lindane | |
| ⅓ | 126.5 |
| ⅔ | 131.3 |
| 1 | 127.3 |
| Heptachlor | |
| ⅓ | 132.8 |
| ⅔ | 133.5 |
| 1 | 125.0 |
| Diazinon | |
| ⅓ | 130.8 |
| ⅔ | 132.0 |
| 1 | 130.0 |

[a] Each value represents the mean of 4 replications consisting of 150 seeds each.

Unfortunately this field was small in size and irregular in shape, and only two replications were practical. Each plot was subdivided into four sampling areas. Wireworm bait traps were put out on three different dates during the growing season. Five traps were spaced about 12 feet apart in the third, fifth, seventh, and ninth rows of each plot. Autoclaved corn and a mixture of equal parts of corn meal and graham flour were placed in alternating rows as wireworm attractants. Baits of consecutive trials were relocated but confined to the same general areas. Stand counts were taken on September, 30 and yields were obtained on October 17, from the general regions sampled earlier for wireworms. Counts of wireworms from the traps and other data are given in table 4.

Stand counts from all three of the soil insecticide treatments were significantly better than that of the control, but there was little difference in the stand when insecticide treatments were compared. As is often the case, the wireworm infestation was not evenly distributed through the field, but in the heavier infested areas the control strip could readily be picked out by visual inspection. The yield data gave no significant differences, due to excessive variation among samples within replications. The grow-

**Table 4.—Combination soil and seed insecticide treatments against wireworms. Centerville, Iowa. 1952.**

| Treatment[a] | Mean No. Plants per 40-Foot Row[b] | Mean Yield (Bu. per A.)[b] | Type of Bait[c] | No. Wireworms Dug from 40 Traps: July 12 | Aug. 19 | Sept. 12 | Total |
|---|---|---|---|---|---|---|---|
| None to soil | 28.6 | 90.6 | corn | 30 | 320 | 4 | 354 |
| | | | mixture | 23 | 65 | 2 | 90 |
| BHC | 35.4 | 105.6 | corn | 4 | 13 | 0 | 17 |
| | | | mixture | 2 | 7 | 1 | 10 |
| Chlordane | 36.0 | 102.7 | corn | 9 | 25 | 8 | 42 |
| | | | mixture | 10 | 15 | 2 | 27 |
| Aldrin | 34.0 | 104.0 | corn | 4 | 10 | 3 | 17 |
| | | | mixture | 1 | 9 | 1 | 11 |
| L.S.D. at 5% level | 4.6 | 30.5 | | | | | |

[a] All soil treatments were emulsions sprayed broadcast and disked into the soil before replanting. Throughout the field lindane wettable powder was applied to the seed at the rate of 4½ ounces of 25 per cent active per bushel.

[b] Each value represents the mean of 2 replications of 4 sub-samples each.

[c] The corn bait consisted of about 120 milliliters of autoclaved spoiled corn per bait trap, while the mixture was roughly 80 milliliters of equal parts of graham flour and corn meal.

ing conditions were above average, which would indicate that there may have been a yield compensation in some regions of reduced stand.

Examination of the bait traps revealed an average for the season of only 0.59 elaterids per trap, but this figure is misleading. Few wireworms were recovered from the baits during a hot and dry summer period. Frequent rains before the August 19 diggings apparently made soil conditions more favorable and the wireworms resumed their feeding activities. On this date the control strips showed an average of about 5 elaterids per trap, against an average of about 0.3 for the insecticide treated strips. Evidently the soil insecticides killed or inactivated a large percentage of the wireworms. Autoclaved corn proved a better attractant than the corn meal-graham flour mixture in this experiment.

*Laboratory experiments with soil insects.*—Exploratory tests to evaluate protection afforded by insecticides were performed with wireworms and seed-attacking beetles exposed to treated seed. The tests were kept as simple as possible to reduce conditions foreign to the insects. The corn was placed at approximately the normal field planting depth with soil as the medium. Six late instar wireworms of *Melanotus communis* Gyll. were placed with an equal number of seeds in a ½-gallon crock for 10 days. Two species of seed-corn beetles (*Agonoderus comma* Fabr. and *Clivina impressifrons* Leconte) were employed in similar tests, except only 4 beetles of a species and 4 kernels of corn were used per replicate. Also, with the beetles the containers were pint fruit jars and the tests were continued for only 5 days. At the end of a test the treatments were evaluated on the basis of how much protection they gave to the germinating seed and how the test insects were affected.

Lindane was tried at six levels before it was compared with heptachlor, dieldrin, toxaphene, and Diazinon. The insecticides were slurried on Pioneer Hybrid 349 with methyl cellulose as a sticker. Two trials were run in both types of tests with wireworms and *Agonoderus comma;* one of each was run with *Clivina impressifrons.* In all tests there were six replications.

The tests were not extensive enough for critical comparisons and no statistical analyses were attempted. Beetles were not selected as to age, and consequently some of them may have died from natural causes during the experiments. Both wireworms and *A. comma* are cannibalistic, a factor that must be considered in comparisons if individual insects found treatments distasteful and turned on their companions as a source of food in the confined conditions of the tests. Furthermore damage to seed was not rated as to severity, but injury was reflected in the seedling emergence figures in the case of wireworms. It was necessary to keep the lids on the jars to prevent beetles from escaping and this appeared to make emergence too erratic for use as a measure of treatment effect. However, certain trends were indicated in some cases in the tests as shown in table 5.

With wireworms both trials with the levels of lindane indicated that there were more wireworms killed, fewer seeds damaged, and slightly more plants emerged with higher dosages of lindane than with the lower ones. There was little difference in the results obtained from the two highest levels. Even the lower dosages had fewer damaged seeds than were found in the controls. Heptachlor, dieldrin, and lindane gave the best results in both trials with the 1-ounce dosages of the five insecticides. Lindane did not give as high a wireworm kill, but it compared favorably with dieldrin and heptachlor in the number of seeds injured. Perhaps lindane expressed part of its seed protection by a repellent action. Diazinon ranked high in its killing but failed to prevent seed injury. Toxaphene gave results little better than those of the control.

In the beetle tests neither species fed actively on the corn during the experiments. Usually damage to seed was not as severe as that caused by wireworms, perhaps partly because of the shorter duration of the beetle experiments. Lindane appeared to be more effective at lower dosages against the beetles than against wireworms. The five insecticides ranked roughly in the same order of killing ability that they did with wireworms, but the results are not clear enough for definite statements.

SUMMARY.—Acetone apparently offers little promise as a solvent for the application of lindane to seed corn. It caused progressive reductions in both stands and yields as the insecticide dosage was increased on Pioneer 379 but not on Pioneer 339. This indicates a difference in susceptibility to insecticide injury between the two hybrids. The addition of either thiram or captan did not appreciably lessen the injury caused by similar dosages of lindane in acetone solution.

Treatments applied with methyl cellulose corresponding to the acetone treatment above showed little or no phytotoxicity to either Pioneer Hybrid 379 or 339 under field conditions, even after storage of the seed for 5 months at any three storage temperatures. Furthermore, methyl cellulose as an adhesive was superior to dry applications of lindane on Pioneer 349, since the clubbing of primary roots was lessened in the slurry method when ½- and 1-ounce dosages of lindane were used.

Corn seedlings grown in soil in a preliminary greenhouse test largely overcame deficiences in green weight caused by high dosages of lindane within 18 days after planting. Although the primary roots of seedlings from lindane-treated seed were still slightly shortened at the

Table 5.—Laboratory experiments with insecticide-treated corn seed exposed to attacking insects while being germinated in soil. 1954.[a]

| Ounces of Lindane | *Melanotus communis* Tests | | | | | | *Agonoderus comma* Tests | | | | *Clivinia impressifrons* Tests | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Wireworms Moribund or Dead | | Seeds Damaged | | Plants Emerged | | Beetles Moribund or Dead | | Seeds Damaged | | Beetles Moribund or Dead | Seeds Damaged |
| | Trial 1 | Trial 2 | Trial 1 | Trial 2 | Trial 1 | Trial 2 | Trial 1 | Trial 2 | Trial 1 | Trial 2 | Trial 1 | Trial 1 |
| None | 4 | 2 | 29 | 26 | 28 | 24 | — | — | — | — | — | — |
| 2 | 15 | 11 | 1 | 0 | 34 | 33 | 2 | 4 | 12 | 8 | 1 | 4 |
| 1 | 14 | 12 | 0 | 5 | 30 | 34 | 23 | 22 | 2 | 2 | 9 | 0 |
| 0.5 | 11 | 8 | 4 | 11 | 31 | 30 | 24 | 18 | 2 | 1 | 12 | 2 |
| 0.25 | 7 | 7 | 10 | 19 | 26 | 31 | 21 | 19 | 0 | 0 | 6 | 0 |
| 0.125 | 8 | 4 | 8 | 17 | 30 | 25 | 16 | 15 | 2 | 0 | 12 | 1 |
| 0.0625 | — | — | — | — | — | — | 15 | 15 | 1 | 4 | 10 | 2 |
| *Other treatments at 1 ounce per bushel* | | | | | | | | | | | | |
| Control | 1 | 2 | 31 | 34 | 26 | 20 | 1 | 7 | 13 | 7 | 5 | 4 |
| Dieldrin | 24 | 18 | 8 | 4 | 34 | 29 | 5 | 12 | 8 | 0 | 11 | 2 |
| Toxaphene | 6 | 2 | 32 | 29 | 21 | 28 | 4 | 9 | 7 | 2 | 6 | 2 |
| Lindane | 12 | 16 | 4 | 6 | 34 | 30 | 19 | 15 | 4 | 1 | 8 | 3 |
| Diazinon | 24 | 27 | 28 | 30 | 22 | 28 | 4 | 13 | 1 | 5 | 4 | 5 |
| Heptachlor | 30 | 28 | 3 | 2 | 33 | 34 | 14 | 22 | 1 | 3 | 16 | 0 |

[a] A total of 36 wireworms and 36 corn seeds were used in each wireworm trial whereas 24 beetles and 24 seeds were employed in trials with beetles.

end of the experiment, the seedling weights and visual observations indicated that they probably had ample root systems.

In a field test subjected to cool, damp weather, captan was not only compatible with three insecticides at various dosages, but also increased the stands of treatments which included this fungicide.

A reduced dosage of lindane seed treatment failed to satisfactorily protect corn seedlings from wireworms in an early planting of corn at Centerville, Iowa. However, soil treatments with insecticides in the replanting gave significant increases in stand, and presumably reduced the number of active wireworms.

Laboratory tests with soil insects were not extensive enough to determine the level of lindane which gave the best protection to treated seed. Heptachlor, dieldrin, and lindane were effective in protecting germinating seed corn against wireworms at 1 ounce of actual ingredient per bushel of seed, and against seed-attacking beetles at $\frac{1}{2}$ ounce per bushel. Diazinon killed about as many wireworms as the other three insecticides, but it failed to satisfactorily prevent damage to the seed. Toxaphene was only slightly effective against wireworms.

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# Studies of Certain Species of *Chaetocnema*

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In connection with studies on the insect vectors of Stewart's disease, or bacterial wilt, of corn (Poos & Elliott 1936, Elliott & Poos 1940), considerable information on the biology of the vectors and certain phases of the insect-disease relationship of the problem, relating particularly to the species of *Chaetocnema* involved, was accumulated over a 12-year period. Because the corn flea beetle, *C. pulicaria* Melsh., was reported as unusually abundant over large areas in several sections of the Eastern States during 1953 and 1954, this paper presents a description of methods used and previously unreported results of these early studies.

Three other species of *Chaetocnema*, listed in the order of their abundance on corn, were encountered in these studies: *denticulata* (Ill.), toothed flea beetle; *confinis* Crotch, sweetpotato flea beetle; and *minuta* Melsh. *C. pulicaria* is the most abundant of these species on corn and is principally responsible for harboring the bacterial wilt organism, *Aplanabacter stewarti* (E. F. Sm.) McC., over winter. It was the only insect found doing this. *C. denticulata* yielded the wilt organism when cultured for it after being collected on corn in summer. *C. confinis* was abundant on corn adjacent to sweet potato plantings or in weedy corn fields containing bindweed or other convolvulaceous weeds. *C. minuta* was encountered only occasionally in the field, mostly in Connecticut and New York, and was therefore not abundant enough for extensive studies. It was abundant on corn in northern Ohio in

[1] Retired from Federal service March 31, 1955.

[2] Assisted by John W. Scrivener and Nancy H. Wheeler, whose invaluable help is gratefully acknowledged. Herbert S. Barber made many species identifications in connection with these studies and the Division of Economic Botany of the former Bureau of Plant Industry, U.S.D.A., made species identifications of grasses and sedges.

1922, when a collection made there was identified by E. A. Schwartz as *pulicaria* and *minuta* in about equal numbers.

MATERIALS AND METHODS.—Life-history studies were conducted in the laboratory and insectary. Extremely high mortality in rearing *pulicaria* in confinement was experienced (less than 7 per cent of the individuals observed hatching were reared to adults). It was evident that the methods used were too artificial; yet owing to the small size of this insect and the fact that in nature its immature stages are spent in the soil, any methods that keep the immature forms accessible for observation are necessarily artificial. Eggs were obtained by placing 12 to 30 adult flea beetles on a few pieces of young tender corn leaves in a 1- by 4-inch glass vial. Each day the adults were transferred to clean vials containing fresh leaves of corn, and the vials and corn leaves that were used the previous day were examined for eggs. These eggs were transferred to 2-ounce tin salve boxes half filled with hardened plaster of Paris, the surface of which was painted with India ink so that the eggs and small larvae could readily be observed.

After an egg hatched, the young larva was placed on a tender leaflet of corn and kept in a salve box as described above. It was necessary to make a slit in the midrib with a fine needle and place the larva in position for feeding in order to be reasonably sure that it would continue its development. Daily examinations were made, with similar precautions when the larva was provided with a fresh leaflet. The condition of the food and the moisture seemed to be the most important factors in the successful rearing of this species in salve boxes. The very young larvae prefer young leaves, but as they develop they seem to prefer older leaves taken from rapidly growing plants. When the larva became nearly full grown, a teaspoonful of moist sterile soil was placed in the salve box to facilitate pupation.

Plants on which *pulicaria* was developing under natural conditions were determined by selecting plants from a pure stand or those sufficiently isolated to preclude migration of the immature stages from one host species to another. The soil to a depth of 6 inches under selected plants was brought into the insectary, where it was placed in a solution containing 6 to 12 per cent of magnesium sulfate in large, shallow enamel pans to float out the immature forms of this insect. Careful examination of the soil surrounding such plants was an exceedingly tedious task; possibly more individuals were overlooked than were found, but it gave information not otherwise more easily obtainable.

In larger cages, covered with fine cheesecloth 2 by 2 by 2½ feet in which large numbers of adults were confined to hills of corn or clumps of grasses in the field, no success in rearing this species resulted. Adult beetles readily escaped from or entered these cages. In similar tests with potted corn plants or flats of bluegrass in the greenhouse a few adults were occasionally reared, but as this method could not be relied on to furnish any desired number of adults it was abandoned.

Live adults of *pulicaria* and *confinis* were separated by shaking them onto a small ice cube and examining them under a binocular microscope.

Hibernating conditions were studied by bringing bluegrass and other sod into the laboratory in winter. The sod was cut at depths of 1, 2, or 3 inches by means of a saw and a frame built for this purpose, and placed in cardboard shirt boxes, 9½ by 13 by 5¼ inches. In one side of each box three holes, approximately 1 inch in diameter, were cut to hold glass vials to catch the emerging flea beetles (Fig. 1).

SEASONAL HISTORY.—*Chaetocnema pulicaria.*—This beetle overwinters in the soil as an adult, and has been recovered only from the top inch. In the Washington, D.C., area it prefers bluegrass sod, but orchard grass, red top, and timothy are also satisfactory. Adults become active in winter when the temperature at the surface of the ground reaches 65° to 70° F. for a few hours, and then they may be collected by sweeping with an insect net close to the surface of the sod. High populations are usually concentrated in sod near late-planted corn of the previous season. As the days become warmer in late April and early May, the adults become generally distributed and then concentrate on seedling corn, where they often skeletonize the leaves so much that the plants die. Sometimes much of the stand is wiped out even in large fields, but this occurs more often in small garden plots of sweet corn. This beetle is thus of considerable economic importance even when it does not transmit bacterial wilt.

Adults overwintered as far north as southeastern Massachusetts near the Atlantic coast during the winter of 1937–8. This beetle passed through at least two complete generations in the field each year at Arlington, Va. There is undoubtedly much overlapping of generations, but in general adults of the first brood appeared in the last half of June and early July and of the second brood about August 10–20.

During the course of these studies a sudden increase in populations of adult beetles was often observed after heavy rain preceded by a week or more of hot, dry weather. Overwintering adults that were confined in glass vials in the outdoor insectary deposited eggs until July 9, and some of these adults lived until August 2. Although corn is the preferred host plant, it is not essential to the perpetuation of the species. The insect was found developing abundantly on various sedges and grasses in the absence of any corn (except in backyard gardens) within approximately 4 miles. In 1940 late-instar larvae and pupae were found developing on wheat, timothy, Bermuda grass, and fall panicum prior to the occurrence of any immature forms, except second-instar larvae, on the earliest corn available at the Arlington Experiment Farm, indicating that a certain proportion of the population normally completes a generation on hosts other than corn before it attacks corn.

Apparently, under natural conditions the eggs are deposited at the base of corn or grass plants and the young larvae feed on the fibrous roots. Attempts to verify this fact by observations in the field or by concentrating several hundred adults on corn or grass plants in field or laboratory cages failed. Larval feeding within the leaves was never observed in nature.

In 1938–42 larvae were found from May 16 until October 9, during which period the soil to a depth of about 6 inches was examined under 568 hills or plants of corn, rye, and various species of grasses that had been

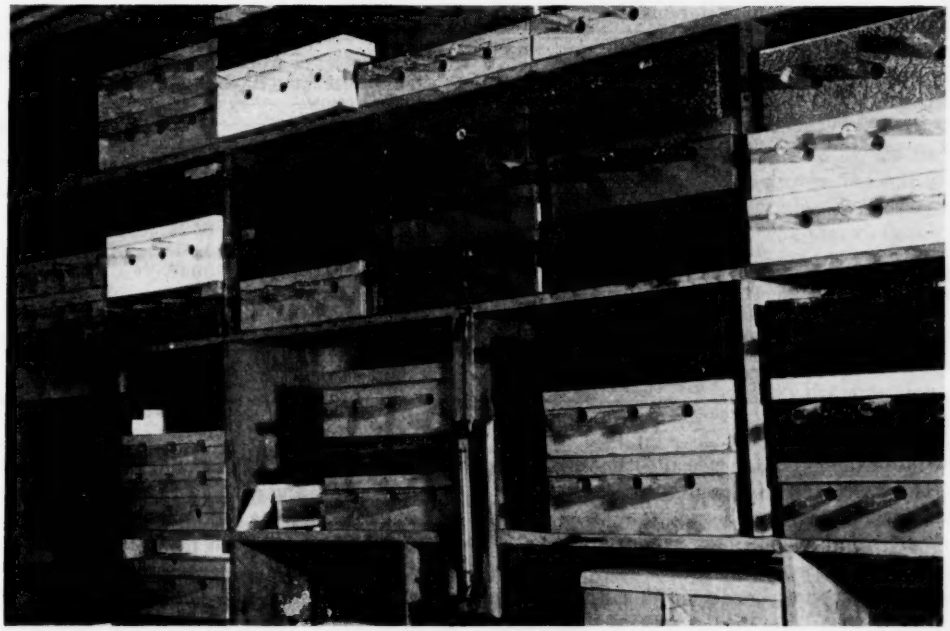

FIG. 1.—A section of shelves showing some of the boxes in which samples of sod (approximately 1 sq. ft.) were placed for emergence of *Chaetocnema* spp. to determine kind of sod in which the beetles hibernate and at what depth in the soil.

fed on in the field by adults of this insect. One larva (early third-instar) was found 6½ inches below the surface of the soil under a corn plant. Adults that failed to emerge and died were found at depths of 2 to 3½ inches. On dissection of adults collected in the field on June 28–29 and August 22, 1938, 101 females and 106 males were recorded.

*Chaetocnema denticulata.*—This species became active in the field in the winter and early spring in much the same way as *pulicaria.* It was a little less active than *pulicaria* or less sensitive to changes in air temperature. Some adults hibernated in the third inch of soil below the surface. It preferred fall panicum although it also developed on sweet corn in the field. On corn the larvae fed on the root system, whereas on fall panicum they only fed above ground. Eggs were found just below the surface of the soil near the base of corn, crabgrass, witchgrass, and fall panicum plants, but above ground they were only found on the fall panicum.

New broods of adults in abundance appeared at irregular intervals depending on the amount of fall panicum available as well as the weather. Judging by their abundance and mating activities, a new brood appeared at Arlington Farm in 1937 on May 21 and another about June 15. Apparently several broods may develop in a single season under optimum conditions.

HOST PLANTS.—*Chaetocnema pulicaria.*—The feeding habits of the adults of this species are discussed, and the amount and type of feeding on the leaves of six species of plants are illustrated by Poos & Elliott (1936). Feeding injury by the adults was observed on the leaves of at least 20 species of Gramineae in the field. Of 33 species of plants in the field examined by washing the soil under them, *pulicaria* was found developing on the following 21 species:

*Agrostis alba* L.—Redtop
*Avena sativa* L.—Oat
*Cynodon dactylon* (L.) Pers.—Bermuda grass
*Cyperus esculentus* L.—Chufa
*Cyperus strigosus* L.—Strawcolored sedge
*Dactylis glomerata* L.—Orchard grass
*Digitaria ischaemum* (Schreb.) Muhl.—Smooth crabgrass
*Digitaria sanguinalis* (L.) Scop.—Crabgrass
*Echinochloa crusgalli* (L.) Beauv.—Barnyard grass
*Eleusine indica* (L.)—Goosegrass
*Eragrostis pectinacea* (Michx.) Nees.
*Elymus virginicus* L.—Virginia wildrye
*Hordeum distichon* L.—Barley
*Lolium multiflorum* Lam.—Italian ryegrass
*Panicum capillare* L.—Witchgrass
*Panicum dichotomiflorum* Michx.—Fall panicum
*Phleum pratense* L.—Timothy
*Setaria faberi* Herrm.
*Setaria lutescens* (Weigel) F. T. Hubb—Yellow bristlegrass
*Triticum aestivum* L.—Wheat
*Zea mays* L.—Maize, Indian corn (field and sweet)

In the laboratory one adult was reared on potato foliage, and some larvae became full-grown on bluegrass, oats, rye, and wheat and half-grown or larger on barley, broad bean, and *Coix* sp. Larvae would not feed on alfalfa. On April 11 and 16, 1941, overwintered adults were collected in the field and placed on various host plants in 1- by 4-inch glass vials to determine their longevity and their plant preference for oviposition. Some of these overwintered adults lived until September 1. Usually 15 adults were confined to a vial and two vials were started with each host plant in each series. Fresh host material was placed in the vials four times weekly. The old material was examined carefully for eggs. The results of these studies are presented in table 1.

Corn was obviously the preferred host for oviposition,

Table 1.—Longevity and plant preference for oviposition by overwintered adults of *Chaetocnema pulicaria*, 1941–42.

| Host Plant | Number of | | | Latest Date of Oviposition | Maximum Days Longevity in Vials | Sex of Adults Examined | |
|---|---|---|---|---|---|---|---|
| | Exposures | Vials | Eggs | | | Females | Males |
| Agropyron | 64 | 4 | 49 | May 26 | 83 | 2 | 6 |
| Alfalfa | 39 | 6 | 0 | — | 24 | 46 | 37 |
| Bluegrass | 174 | 6 | 363 | June 23 | 90 | 34 | 31 |
| Corn | 193 | 6 | 663 | 30 | 100 | 31 | 19 |
| Cowpea | 21 | 2 | 11 | May 19 | 35 | 16 | 11 |
| Dock | 19 | 4 | 0 | — | 11 | 25 | 26 |
| Orchard grass | 249 | 6 | 342 | June 27 | 139 | 37 | 25 |
| *Panicum tsugetorum* | 41 | 2 | 35 | 15 | 74 | 21 | 11 |
| Peanut | 8 | 2 | 0 | — | 11 | 16 | 15 |
| Plantain | 4 | 1 | 0 | — | 8 | 2 | 1 |
| Potato | 34 | 4 | 3 | April 22 | 42 | 36 | 23 |
| Timothy | 174 | 6 | 448 | June 24 | 90 | 31 | 22 |

although several of the grasses, especially timothy, bluegrass, and orchard grass, were acceptable. Plants showing no evidence of feeding by the adults and on which no eggs were deposited in the vials were alfalfa, broad bean, dock, peanut, and sweet potato. A male collected April 16 lived 139 days on orchard grass in the glass vials, or until September 1. All the beetles used in these tests were overwintered adults, thus adding a minimum of approximately 6 months to their total longevity.

*Chaetocnema denticulata.*—The feeding habits of adults of this species are discussed and the type of injury on the leaves of three species of plants is illustrated by Poos & Elliott (1936). Feeding was observed on the leaves of a number of grasses occurring in the field at the Arlington Experiment Farm. By the same method used for *pulicaria*, *denticulata* was found developing in nature on the following species:

*Cyperus ferax* Rich.
*Cyperus strigosus* L.—Strawcolored sedge
*Digitaria ischaemum* (Schreb.) Muhl.—Smooth crabgrass
*Digitaria sanguinalis* (L.) Scop.—Crabgrass
*Echinochloa crusgalli* (L.) Beauv.—Barnyard grass
*Eleusine indica* (L.)—Goosegrass
*Panicum capillare* L.—Witchgrass
*Panicum dichotomiflorum* Michx.—Fall panicum
*Secale cereale* L.—Rye
*Setaria lutescens* (Weigel) F. T. Hubb—Yellow bristlegrass
*Zea mays* L.—Maize, Indian corn

W. R. Walton observed this species seriously injuring barley at Arlington, Va. on June 17, 1914, where fully one-third of the plants appeared stunted and showed signs of recent injury, particularly the dried and shriveled appearance of the growing point. This was caused by the feeding of the larva at the base of the central shoot, resulting in severing the leaf and its consequent death.

In October of 1940 this species was reported injuring wheat severely in two localities in Kansas and Oklahoma.

LIFE HISTORY.—*Chaetocnema pulicaria.*—The egg (Fig. 2) is white and semitranslucent. Ten eggs averaged 0.41 mm. in length and 0.19 mm. in width. The surface of the egg (as viewed under high magnification with proper light) is finely, irregularly, but densely punctate. Eggs were obtained more abundantly in confinement when the adults were fed young tender corn leaves, although the adults subsist on a wide variety of plants both under artificial conditions and in the field. The incubation period of 132 eggs in the insectary ranged from 4 to 10 days and averaged 6.2 days, whereas that of 107 eggs kept in the laboratory at the same time during July and August ranged from 2 to 6 days and averaged 4.4 days. The time of development from hatching to full-grown larva during the same months ranged from 11 to 15 days, and the average for 7 individuals was 14 days.

Records on the stages of development of this insect as observed under controlled conditions are summarized in table 2.

The larva is about 4.5 mm. long when fully grown. The adults (Fig. 6) ranged from 1.5 to 1.8 mm. in length. Adults collected in the field during warm periods in January began to deposit eggs in large numbers after feeding 6 days on tender corn leaves in glass vials kept at 80° F. Similarly, adults collected in October and kept on corn or bluegrass in cheesecloth-covered cages in the green-

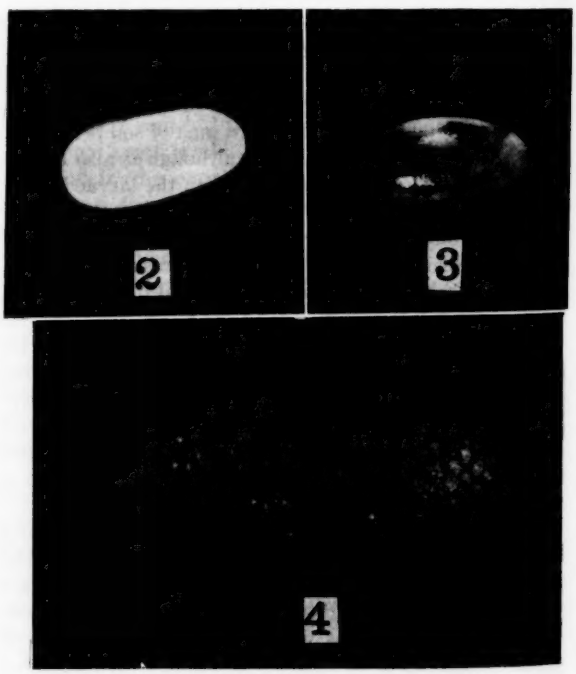


FIG. 2.—Egg of *C. pulicaria*. Average length, 0.41 mm.
FIG. 3.—Egg of *C. confinis*. Average length, about 0.37 mm.
FIG. 4.—Egg of *C. denticulata*. Average length, about 0.6 mm.

Table 2.—Duration of stages of development of *Chaetocnema pulicaria* and *C. denticulata* under controlled conditions.

| Stage | Number of Records | Duration in Days | |
|---|---|---|---|
| | | Range | Average |
| | *pulicaria* | | |
| Incubation period | 495 | 4–10 | 5.8 |
| Larval | 62 | 10–23 | 15.8 |
| Prepupal | 24 | 1– 5 | 2.1 |
| Pupal | 20 | 3– 7 | 5.3 |
| Egg to adult | 33 | 22–36 | 29.7 |
| | *denticulata* | | |
| Incubation period | 134 | 4–11 | 6.5 |
| Larval | 53 | 10–21 | 14.2 |
| Prepupal | 55 | 1– 6 | 2.5 |
| Pupal | 43 | 3– 8 | 6.2 |
| Egg to adult | 23 | 24–31 | 28.3 |

house at approximately 65° F. until February 18 produced eggs abundantly when confined with tender corn leaves in glass vials kept at 80° F.

*Chaetocnema denticulata.*—The egg is about 0.6 mm. long and pale yellow (Fig. 4). The surface is uniformly and heavily sculptured. The life-history records on this species as shown in table 2, were made at the same time and under conditions and by methods similar to those used for *pulicaria* except that the plant used for larval food was fall panicum. This plant was mistakenly called Johnson grass in an earlier publication (Poos & Elliott 1936).

The larvae of this species have been found developing on the tender unfurled leaves or on the immature seed heads of fall panicum. Some eggs were found below the soil surface on this host, and a few larvae were found feeding on the roots of sweet corn, as is customary for *pulicaria*. The larva is of a dirty-white color and up to 4 mm. long, and bears numerous dark, sclerotized, rounded areas on its dorsal and lateral surfaces.

The adults (Fig. 5) ranged from 2.3 to 2.8 mm. in length and became active on warm days in winter much as *pulicaria* does. However, no eggs were ever obtained in winter from these adults when kept by the same method that was successful with *pulicaria*. Comparatively few eggs were obtained by this method at any time, but they were readily obtained by placing adults in cages on fall panicum plants growing in soil, where they were deposited just below the surface near the base of the plant.

*Chaetocnema confinis.*—Eggs of this species were obtained by the same method used for *pulicaria* except that tender leaves of bindweed or sweet potato were placed in the vials instead of corn. Seven eggs averaged 0.37 mm. in length and 0.18 mm. in width. The eggs (Fig. 3) are much like those of *pulicaria* in shape, color, and sculpturing. In 1936 the incubation period for 10 eggs ranged from 6 to 8 days and averaged 6.9.

Attempts to get the larvae to complete their development on leaves or roots of sweet potato or bindweed in salve boxes as corn leaves were used for *pulicaria* were unsuccessful. In 1938 incubation records on 174 eggs showed that hatching required a minimum of 3 days and a maximum of 14 days. Larval development of 7 individuals ranged from 5 to 18 days. Two individuals developed from egg to prepupa in 18 and 23 days, and from egg to pupa in 19 and 25 days. Roots and stems of sweet potato and bindweed were again placed in salve boxes with 171 larvae, but without success. In numerous attempts by another method only one individual was reared to adult by placing the newly hatched larva on a small potted bindweed plant. After the larva had had time to become nearly full grown, the soil was examined and the larva recovered and placed on roots of bindweed in a salve box, where it completed development, soil being added for pupation.

Adults ranged from 1.5 to 1.8 mm. in length.

*Chaetocnema minuta.*—This species was not found in the Arlington area until 1940, when a few adults emerged from the top inch of bluegrass or orchard grass sod brought into the laboratory in connection with studies on hibernation of other species of *Chaetocnema*. In 1941 additional adults were obtained from orchard grass sod in similar studies, and two individuals were reared on corn leaves during the period June 2–26. The egg (Fig. 7) is roughly sculptured and about 0.7 mm. long and 0.27 mm. in greatest width. The incubation period was 7 days (of 45 eggs under observation from May 21 to June 30 only 3 hatched), the larval period 11 days, and the pupal period 6 days. The adult (Fig. 8) resembles *denticulata* more than *pulicaria* or *confinis*. The adults ranged from 1.8 to 2.0 mm. in length.

Three overwintered adults that emerged from orchard grass on March 30 and were kept on fresh corn leaves in glass vials in the insectary lived until October 8, 11, and 18, respectively. A few eggs, all infertile, were deposited by these beetles as late as October 8. They undoubtedly lived in the adult stage more than a year. One lived 193 days in a glass vial to which fresh corn leaves were added four times a week.

PARASITES.—The only parasite reared from any of the *Chaetocnema* species included in this study was an egg parasite of *denticulata*. It was reared at the Arlington Experiment Farm and identified by A. B. Gahan as *Anaphoidea pullicrura* Girault. Some eggs of *denticulata* were exposed to a few adult parasites, and the maximum period of development from egg to adult recorded in late August was 11 days. Only females were reared, and apparently only one individual developed within each host egg, although this was not definitely established.

CONTROL.—The effectiveness of DDT against *pulicaria* was determined in 1944 (Poos 1945), but the best mixtures, dosages, and treatment schedules were not determined. During the period 1945–52 the following insecticides were tested against this insect on small plots of early sweet corn at Beltsville, Md., with a view toward finding something to recommend to the small gardener:

*Dusts*
Chlordane, 5%
BHC, gamma 0.5%
DDT, 2 and 4%
Heptachlor, 5%
Parathion, 1%
Perthane, 5%
Toxaphene, 5%

*Emulsion Sprays*
Aldrin, 1%
DDT, 2 and 4%
Lindane, 1%
Methoxychlor, 2%
Schradan, 1–600
*Wettable-Powder Sprays*
Lindane, 0.75%
Ryania, 1 oz. per gal.
Toxaphene, 0.04%

The 4% DDT emulsion was the most effective formulation tested and caused no plant injury. However, fre-

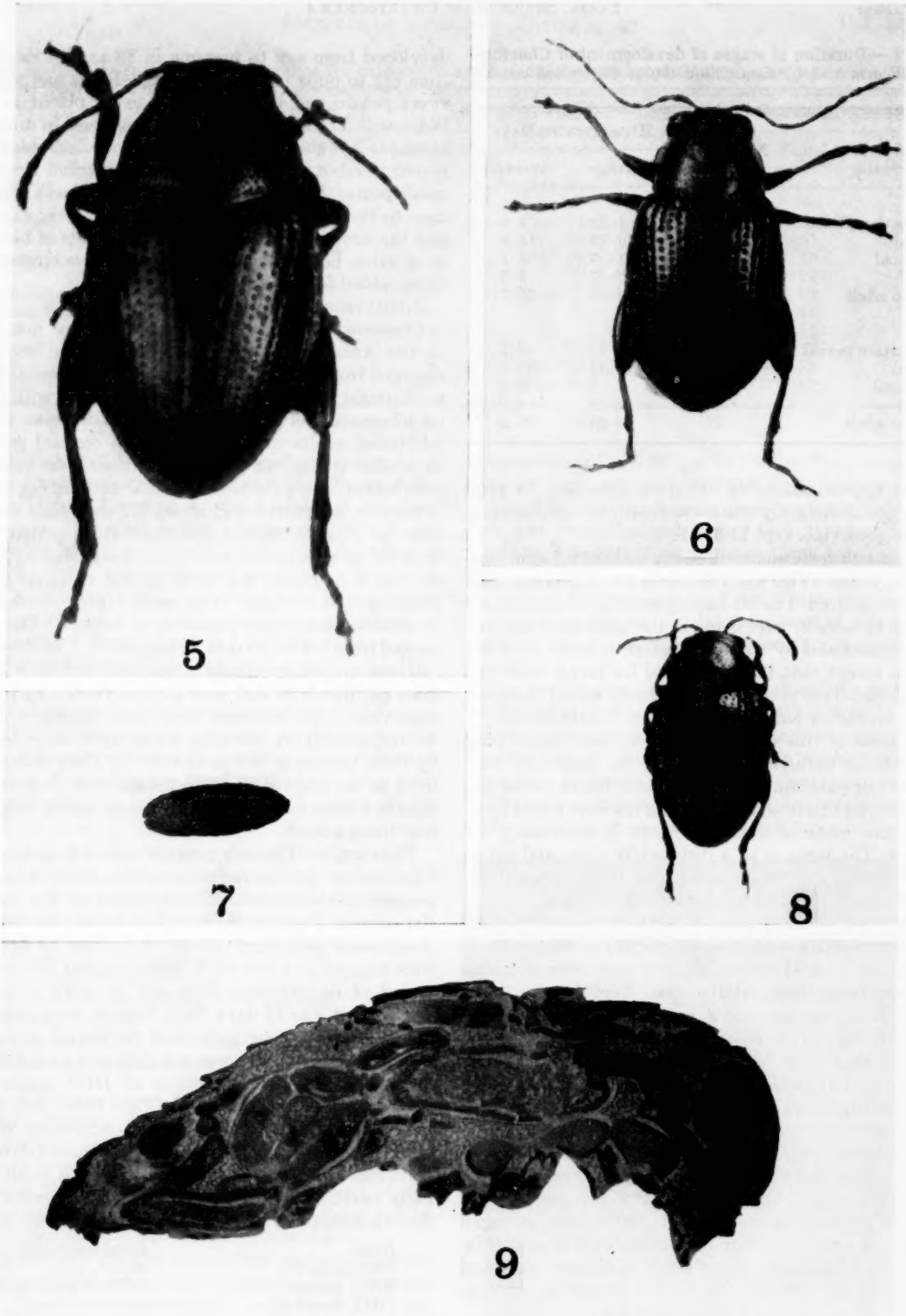


FIG. 5.—Adult of *C. denticulata*. Average length, about 2.6 mm.
FIG. 6.—Adult of *C. pulicaria*. Average length, about 1.6 mm.
FIG. 7.—Egg of *C. minuta*. Average length, about 0.7 mm.
FIG. 8.—Adult of *C. minuta*. Average length, about 2 mm.
FIG. 9.—Longitudinal section of an adult *Chaetocnema pulicaria*, showing gross internal anatomy. Enlarged about 70×. The alimentary tract from the mouth to the posterior end of the mid-intestine is intact in the plane of this section. Note the large brain. The three anterior ganglia of the ventral nerve cord are also in the plane of this section, while the fourth is not clearly shown. The ventral margin in the leg region is broken up.

quent dusting with 3 to 5% DDT dust would doubtless give adequate protection of early sweet corn and avoid the risk of severe injury to corn seedlings by at least some brands of emulsion concentrates when used at optimum dosage of DDT, as observed in New Jersey by Pepper (1954).

On June 10, 1949, A. H. Yeomans treated about 8 acres of valuable strains of hybrid corn that was being severely injured by *pulicaria* at Beltsville, Md. He used a mist blower because the corn was planted on ridges so spaced that other methods of treatment were impractical. From 12 to 14 gallons of a formulation made up of 12 pounds of DDT, 4 gallons of xylene, and 5 gallons of Vapona D-43 oil were applied to the entire area. Counts made 3 days later revealed a phenomenal cleanup of this insect. No damage to the corn leaves occurred, although the spray was heavy enough to wet some of them.

During 1953 and 1954 Adams & Chupp (1954), Adams (1954) and Pepper (1954) made excellent progress in protecting large plantings of early sweet corn in New York and New Jersey from attacks by *pulicaria*. Of equal or more importance, these investigators also controlled the bacterial wilt of corn, of which this insect is a very efficient vector. Several applications of DDT were made at intervals of about 5 days, beginning when the corn was coming through the ground. The beetles were thereby prevented from damaging the corn either by feeding on it or by inoculating it with the wilt organism.

DIRECT INOCULATION TESTS.—Adults of *pulicaria* were disinfected externally, crushed in distilled water, and used to inoculate susceptible corn growing in the greenhouse to produce symptoms of bacterial wilt as proof of the presence of the organism. For some of these tests adults were collected in obscure places (at considerable distances from where corn was grown the previous season) or at unusual seasons of the year in an attempt to learn whether such beetles were carrying the wilt organism. In all tests except one, in which only two adults were available, positive symptoms were produced, indicating that the beetles migrate more than would normally be expected on the assumption that they have to feed on infected corn to become infectious.

SYMPTOMLESS HOST PLANTS.—Another explanation for the high percentage of infectious beetles is that symptomless host plants, other than corn, may furnish wilt organisms with which the adults become infested when they feed on them. In 1940 inoculations into susceptible sweet corn confirmed previous work (Poos 1939) showing that symptoms of bacterial wilt were produced in the greenhouse with inoculum made from the expressed juice of witchgrass, fall panicum, goosegrass, Bermuda grass, and crabgrass collected in the field adjacent to plantings of wilt-infected sweet corn. These plants were taken in the field in July or August and exhibited feeding marks by adults of *pulicaria*. Twelve adults that appeared to be of a new brood were collected on field corn at Williamsburg, Va., on June 29. Neither the corn on which these beetles were feeding nor any corn in the immediate area exhibited symptoms of bacterial wilt; yet when these adults were disinfected externally, crushed in distilled water, and used to inoculate susceptible corn, very severe symptoms of the disease resulted. These observations are representative of several which indicate need for a further study of symptomless host plants of bacterial wilt to explain the cyclic outbreaks of this disease on corn.

INSECT VECTOR-PLANT PATHOGEN RELATIONSHIPS.—A number of adults of *pulicaria* and *denticulata* were sectioned with a microtome and the serial sections stained in an attempt to gain a knowledge of the internal morphology of these vectors of bacterial wilt of corn. It seemed important to learn, if possible, the reason for the differences in effectiveness of the vector species and more of the relationship between the bacteria and their insect vectors. A photomicrograph illustrating the gross internal anatomy of *pulicaria* is shown in Fig. 9. Bacteria resembling *Aplanobacter stewarti* in size and shape appeared to be abundant in the crop of this insect, but it is improbable that this organism can be definitely identified within the insect even if found there abundantly, because its morphological characters are not sufficiently distinctive.

Repeated inoculations on corn with cultures made from feces of *pulicaria* macerated in distilled water produced typical symptoms of the wilt. It thus seems evident that the organism is present throughout the alimentary tract. Similar inoculations indicated that *stewarti* also passed through the alimentary tract of *denticulata* in a viable condition. Inoculation tests yielded positive symptoms of bacterial wilt with fecal material deposited on March 15–18, 1944, by beetles collected on November 20, 1943, and confined to uninfected corn at 75° F. in the greenhouse in the interim. These adults were kept in an unheated garage until January 26. In the greenhouse they were transferred twice weekly to fresh uninfected corn leaves in 1- by 4-inch glass vials. These results suggest, but do not prove, that *stewarti* may multiply within the alimentary tract of the beetle.

Eggs of *pulicaria* were cultured for the presence of *stewarti*. In 1936 when 130 eggs (of which 61 were externally disinfected) were cultured, one culture of 3 eggs dissected from a female beetle yielded the organism. Contamination is suspected in this test, because in 1937 a total of 172 eggs were used in 10 cultures to inoculate 19 susceptible corn plants without producing any symptoms of bacterial wilt.

In a series of nine tests 20 newly emerged adults of *pulicaria* reared from immature forms collected in the field were disinfected externally and tested to determine whether *stewarti* was present before they fed on infected plants. All tests were negative. In another experiment 14 adults reared under laboratory conditions were cultured for *stewarti* with only negative results. All evidence obtained in these studies indicated that the bacterial wilt organism did not accompany its insect vector through its life cycle.

EFFECT OF LOW TEMPERATURES.—The effect of low temperatures on adults of *pulicaria* and on *stewarti* harbored by this insect was studied by holding the beetles in insulated boxes cooled by solid carbon dioxide. The beetles were collected during periods of mild weather in winter or in the spring, usually when they began to emerge from hibernation. Temperatures in each box were recorded by means of a hygrothermograph, checked by standard U. S. Weather Bureau maximum and minimum thermometers. The beetles were placed on strips of paper towels in 1- by 4-inch cotton-stoppered vials, which were then enclosed in Mason jars and sealed to prevent

contact with the carbon dioxide gas. The effect on *stewarti* within the beetles was determined by inoculation tests as described above under "Direct Inoculation Tests."

The results of 18 tests are presented in table 3. During 1936–39 many adults survived exposure of 2° F. for a few hours, but at −5° F. all were killed. In 1940 these results were confirmed when 45 of 150 over-wintered adults had survived exposure to 6° from April 30 to May 6 whereas none of the same number in a similar box at 0° survived. Because the second group of beetles emerged from hibernation more than a month later than in previous years, it is assumed that many of them had been active in April and were therefore less able to withstand a sudden change to lower temperatures.

The low temperatures in these tests did not affect the viability of *stewarti*. One test in which dead beetles that had been exposed to 0° F., and in which the temperature remained at 15° or below for 72 hours, were used for inoculum 7 days after being removed from the testing box, produced typical symptoms of wilt. In other tests comparatively short exposures to −10° were not fatal to the wilt organism within the insect. The organism lived for 48 hours in dead adults kept in the freezing chamber of a refrigerator. Low temperatures were more unfavorable to *pulicaria* than to the wilt organism within it. General observations indicated that more adults survived uniformly cold winters in the Washington, D. C., area than winters having several mild periods (when the adults become active) followed by rapid changes to much lower temperatures.

DISCUSSION.—The principal objective of these studies was not reached—that is, to explain the cyclic appearance of destructive outbreaks of bacterial wilt of corn. From the information accumulated it seems apparent that a better knowledge of the influence of the ecological and other factors, both on the insect vector and upon the disease itself, is necessary. Observations indicated that heavy populations of *pulicaria* are not necessarily followed by a severe outbreak of bacterial wilt of corn. The time of occurrence on its various host plants and the factors responsible for increases in abundance are undoubtedly of considerable importance. It seems to be equally important to know how the beetle becomes infective in nature and what the principal sources of inoculum are under various conditions.

SUMMARY.—Studies were made in the vicinity of Washington, D. C., on the biology of four species of *Chaetocnema—pulicaria* Melsh., *denticulata* (Ill.), *confinis* Crotch, and *minuta* Melsh.—in connection with the

**Table 3.—Effect of low temperatures on adults of *Chaetocnema pulicaria* and on *Aplanobacter stewarti* harbored by this insect, Arlington, Va., 1936–40.**

| Date Collected | Period of Test | Minimum Temperature, ° F. | Number of Adults Tested | Per Cent Adults Survived | Inoculations with Cultures Made from[a]: Dead Adults — Total Used | Dead Adults — Cultures Made | Dead Adults — Plants Inoculated + [b] | Dead Adults — Plants Inoculated − | Living Adults — Total Used | Living Adults — Cultures Made | Living Adults — Plants Inoculated + | Living Adults — Plants Inoculated − |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *1936* | | | | | | | | | | | | |
| Feb. 25 | Mar. 2–6 | 12 | 21 | 90.4 | 0 | | | | 0 | | | |
| | | 5 | 25 | 32.0 | 0 | | | | 0 | | | |
| Mar. 25 | 26–Apr. 1 | −11.5 | 150 | 0 | 0 | | | | 0 | | | |
| | | − 5 | 150 | 0 | 0 | | | | 0 | | | |
| Apr. 14 | Apr. 15–20 | −25 | 125 | 0 | 0 | | | | 0 | | | |
| | | −12 | 125 | 0 | 0 | | | | 0 | | | |
| *1937* | | | | | | | | | | | | |
| Jan. 9 | Jan. 11–13 | 2 | 47 | 38.3 | 0 | | | | 4 | 4 | 4 | 0 |
| | | − 5 | 48 | 2.0 | 0 | | | | 0 | | | |
| | 14–18 | 3 | 50 | 56.0 | 0 | | | | 27 | 27 | 5 | 22 |
| | | − 6 | 50 | 0 | 19 | 19 | 3 | 16 | 0 | | | |
| Mar. 25 | Mar. 26–29 | 0 | 49 | 0 | 49 | 49 | 8 | 41 | 0 | | | |
| | | −15 | 50 | 0 | 50 | 50 | 4 | 46 | 0 | | | |
| *1938* | | | | | | | | | | | | |
| Apr. 12 | Apr. 13–18 | −10 | 150 | 0 | 0 | | | | 0 | | | |
| | | 2 | 150 | 57.3 | 0 | | | | 0 | | | |
| *1939* | | | | | | | | | | | | |
| Mar. 24 | Mar. 25–30 | − 5 | 150 | 0 | 150 | 5 | 1 | 14 | 0 | | | |
| | | 4 | 150 | 47.3 | 116 | 5 | 3 | 12 | 30 | 1 | 0 | 3 |
| *1940* | | | | | | | | | | | | |
| Apr. 29 | Apr. 30–May 6 | 6 | 150 | 30.0 | 105 | 5 | 12 | 7 | 45 | 2 | 4 | 1 |
| | | 0 | 150 | 0 | 150 | 6 | 15 | 7 | 0 | | | |

[a] Beginning in 1937 cultures were made from dead or living *pulicaria* taken from the insulated boxes and tested by inoculations on corn. Only one adult was used per culture with which a single corn plant was inoculated; in 1939 and 1940 21 to 30 adults were used per culture and several plants were inoculated with each culture.

[b] Typical symptoms of bacterial wilt appeared in these plants.

investigations of the insect vectors of bacterial wilt of corn caused by *Aplanobacter stewarti* (E.F. Sm.) McC. *C. pulicaria* was the most efficient vector and it passed through at least two generations annually. It was found developing on 21 host plants. Although a preferred host plant, corn was not necessary for this insect to survive in abundance. It overwintered as an adult in the top inch of bluegrass sod, but orchard grass, red top, and timothy also provided satisfactory hibernating conditions.

Adults of *denticulata* also overwintered in sod, sometimes more than 2 inches below the soil surface. It was found developing on 11 host plants but preferred fall panicum, *Panicum dichotomiflorum* Michx.

In laboratory tests the adults of *pulicaria* survived a temperature of 5° F. or below for only a few hours. The viability of the wilt organism, when harbored by the beetle, was not affected by temperatures that proved fatal to the insect.

The wilt organism passed through the alimentary tracts of adults of *pulicaria* and of *denticulata* in a viable condition. It was not cultured from eggs of *pulicaria* or from adults reared on uninfected corn. Five species of symptomless grasses located near infected corn upon which *pulicaria* had fed were found to harbor the bacterial wilt organism. Of the formulations tested, DDT, either in an emulsion spray or in a dust, was found to be the most effective for control of *pulicaria*. Several applications, beginning when the corn is coming through the ground, are recommended to the small gardener as a means of preventing losses in stand from the ravages of this insect or from attacks by bacterial wilt of which this beetle is the principal vector.

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# Poison Baits for the Control of Blow Flies and House Flies[1]

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Blow flies usually are present in large numbers in and around slaughter houses, rendering plants, poultry establishments, garbage dumps, and other situations where filth is allowed to accumulate. Although they have not definitely been shown to be responsible for outbreaks of certain diseases, most of them are filth breeders and are capable of mechanically transmitting diseases and parasites of man and animals. DeLong & Boush (1952) found blow flies more abundant than house flies in 15 of 16 collections made in food markets in towns and cities widely distributed over Ohio.

During the past season extensive tests with poison baits were conducted in situations where blow flies and house flies occurred in large numbers. Many of them gave excellent control of house flies but were relatively ineffective against blow flies. Subsequently a number of new formulations and several methods of application were tried with somewhat better results. The results with the best of them are presented in this paper.

Studies by Gahan *et al.* (1954a and b) showed that excellent control of house flies could be obtained with malathion, Diazinon, or Bayer L 13/59 in liquid baits containing blackstrap molasses, sugar, or corn syrup, or dry baits prepared from granulated sugar. Langford *et al.* (1954) found that by spraying garbage cans with liquid baits containing malathion, water, and sugar, the house fly and blow fly population of a town could be reduced as much as 50 per cent during a 10-day period. Bruce (1953) found that baits containing corn syrup and Bayer L 13/59 remained toxic to house flies in screened buildings for several weeks.

MATERIALS AND METHODS.—Chlorthion, Bayer L 13/59, Shell OS 2046 (1-carbomethoxy-1-propen-2-yl dimethyl phosphate), Shell OS 1808 (1-carbomethoxy-1-propen-2-yl diethyl phosphate), and malathion were tested in malt bait; Chlorthion, Shell OS 1808, malathion, and Bayer L 13/59 in sugar cane-blackstrap molasses bait; and Bayer L 13/59 in sugar-water bait.

The baits were prepared by mixing the desired amount of a techical grade of the insecticide directly with malt or blackstrap molasses, by mixing emulsifiable concentrates with blackstrap molasses or blackstrap molasses and water or by dissolving a commercial sugar bait in water. The baits were distributed in dribbles or thin ribbons with a drip can, spatula, plunger-type oil can, sprayer, or sprinkling can where flies were feeding or congregating. Estimates of the fly populations were

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[2] P. H. Adcock and C. R. Crittenden assisted in these tests.

determined by counting the flies feeding on strips of cloth (1 by 24 inches) saturated with 50 per cent malt-water solution, after 5-minute exposures at selected locations. The effectiveness of the treatments was based on the difference in fly counts before and at various intervals after treatment.

TESTS AT A RENDERING PLANT.—Malt baits containing 1 per cent of Chlorthion, Bayer L 13/59, Shell OS 1808, or Shell OS 2046 were tested at a rendering plant against several species of blow flies, principally *Callitroga macellaria* (F.). The plant processed dead animals, bones, and offal from farms, meat markets, and slaughter houses. The bones and offal were collected daily in open steel drums and transported to the plant, and large numbers of flies were brought in with each load. During processing, the offal was run through a shredder and washer to remove the contents from the stomach and intestines. No fly control was practiced at the plant, either by sanitation or with chemicals. Three baits were tested consecutively, with an interval between each test to permit a buildup of the fly infestation. Six hundred grams of the bait was applied daily with a spatula in thin strips on the dead animals, bone and offal barrels, shredder, and other places where flies were feeding or congregating. Results of these tests are presented in table 1.

Baits containing Shell OS 2046 or Shell OS 1808 were the most effective, giving nearly complete control throughout the 3-day test period. Chlorthion and Bayer L 13/59 were slightly less effective for 2 or 3 days but showed almost complete control after the fourth treatment.

TESTS ON SMALL GARBAGE AND TRASH PILES.—Tests were conducted to evaluate the effectiveness of bait containing 1 per cent of technical Chlorthion in malt extract for the control of blow flies, principally *Phaenicia cuprina* (Wd.), on small garbage and trash heaps in a substandard section of Orlando, Fla. Previous testing with various dry baits had reduced the house fly populations to insignificance, but moderate populations of blow flies remained. Approximately 25 grams of the bait was dribbled in thin strips from a plunger-type oil can in each of 30 locations daily. The results are presented in table 2.

Throughout the test period the reduction of blow flies 4 hours after treatment was greater than at 10 minutes and 24 hours. Control was moderate after the first treatment, good after the second, and excellent during the remainder of the period. Reduction of flies 10 minutes and 24 hours after treatment increased gradually throughout the test period from fair the first day to excellent after the fifth treatment.

**Table 1.—Daily applications of malt baits containing 1 per cent of various insecticides against blow flies at a rendering plant.**

| Insecticide | Pre-treatment Count | Per Cent Reduction— 1st Day | 2nd Day | 3rd Day | 4th Day |
|---|---|---|---|---|---|
| Shell OS 1808 | 861 | 98 | 96 | 96 | — |
| Shell OS 2046 | 566 | 99 | 99 | 97 | — |
| Chlorthion | 1,133 | 71 | 86 | 91 | 97 |
| Bayer L 13/59 | 231 | 56 | 81 | 86 | 99 |

**Table 2.—Daily applications of malt bait containing 1 per cent of Chlorthion against blow flies on 30 garbage and trash heaps.[a]**

| Time After Most Recent Treatment | Per Cent Reduction 1st Day | 2nd Day | 3rd Day | 4th Day | 5th Day |
|---|---|---|---|---|---|
| 10 minutes | 45 | 65 | 74 | 81 | 94 |
| 4 hours | 77 | 87 | 94 | 98 | 96 |
| 24 hours | 52 | 50 | 67 | 87 | 90 |

[a] Pretreatment counts averaged 16 flies.

TESTS ON PUBLIC GARBAGE DUMPS.—Tests were conducted to evaluate the effectiveness of four baits for the control of house flies and blow flies, principally *Callitroga macellaria*, on garbage dumps in Sarasota County, Fla. The baits contained 0.2 per cent of Bayer L 13/59 and 20 per cent of sugar in water, 1 per cent of Shell OS 2046 or Shell OS 1808 in malt, or 2 per cent of malathion (from an emulsifiable concentrate) in blackstrap molasses or malt. The bait containing Bayer L 13/59 in sugar solution was applied with a sprinkling can. The baits containing insecticides in blackstrap molasses or malt were dribbled on the infested area with a spatula or drip can. The baits were applied only to the parts of the dump on which flies were feeding or congregating. The results are given in table 3.

All the baits gave more than 90 per cent control of house flies at each observation period. The baits containing Shell OS 2046, Shell OS 1808, or malathion in malt also gave satisfactory control of blow flies, but malathion in blackstrap molasses was unsatisfactory, and the sugar solution of Bayer L 13/59 was unsatisfactory after 24 hours. However, the results indicate that good control with all these baits could be obtained with repeated treatments over a period of several days, and the additional cost of mait extract probably would not justify its choice over molasses.

Tests were conducted to determine the relative effectiveness of baits containing from 10 to 98 per cent of blackstrap molasses and 2 per cent of malathion against house flies and blow flies on garbage dumps in Orange and Seminole Counties, Fla. The baits were prepared by diluting blackstrap molasses-malathion concentrate with water and were applied with a 3-gallon compressed-air sprayer at the rate of 1 gallon per 1,000 square feet on locations where flies were feeding or congregating. The whirl plate was removed from the nozzle of the sprayer to apply the bait in heavy drops or streamers. The results of these tests are summarized in table 4.

Baits containing 50 or 75 per cent of molasses were the most satisfactory against both species. The lower concentrations gave lower reductions after 24 hours, which may be attributed to soaking into the dump medium. The 98 per cent molasses was too thick for ready application from the sprayer.

Further tests were conducted on dumps in the same counties to compare baits containing 1 per cent of Shell OS 1808 or 2 per cent of technical malathion, Chlorthion, or Bayer L 13/59 and 50 per cent of blackstrap molasses against house flies and blow flies. The tests were run in

Table 3.—Tests with baits for the control of blow flies and house flies on garbage dumps in Sarasota County, Fla.[a]

| Insecticide | Per Cent Concentration | Attractant | Amount of Bait | Area Treated (Square Feet) | Per Cent Reduction After Treatment: House Flies 10 Minutes | House Flies 4–6 Hours | House Flies 24 Hours | Blow Flies 10 Minutes | Blow Flies 4–6 Hours | Blow Flies 24 Hours[b] |
|---|---|---|---|---|---|---|---|---|---|---|
| Bayer L 13/59 | 0.2 | 20% sugar solution | 5 gallons | 10,000 | 99 | 97 | 94 | 95 | 87 | 64 |
| Shell OS 2046 | 1 | Malt | 10 ounces | 600 | 96 | 97 | 98 | 89 | 94 | 86 |
| Shell OS 1808 | 1 | Malt | 1.5 pounds | 3,500 | 96 | 98 | 96 | 97 | 99 | 85 |
| Malathion | 2 | Blackstrap molasses | 25 pounds | 16,000 | 93 | 97 | 99 | 42 | 74 | 49 |
| | | Malt | 12 pounds | 8,000 | 99 | 99 | — | 94 | 95 | — |

[a] Two treatments with first three baits and one with each malathion bait.
[b] Readings taken after one treatment only.

Table 4.—Baits containing 2 per cent of malathion and various concentrations of blackstrap molasses against house flies and blow flies on garbage dumps.[a]

| Per Cent of Molasses | Per Cent Reduction After Treatment: House Flies 10 Minutes | House Flies 4 Hours | House Flies 24 Hours | Blow Flies 10 Minutes | Blow Flies 4 Hours | Blow Flies 24 Hours |
|---|---|---|---|---|---|---|
| 98 | 87 | 71 | 88 | 64 | 55 | 86 |
| 75 | 80 | 80 | 63 | 77 | 82 | 73 |
| 50 | 78 | 89 | 80 | 85 | 80 | 79 |
| 25 | 91 | 90 | 22 | 70 | 43 | 11 |
| 10 | 82 | 90 | 57 | 55 | 73 | 12 |

[a] Averages of three replications.

Table 5.—Tests with baits containing 50 per cent of blackstrap molasses and various insecticides against house flies and blow flies on garbage dumps.

| Insecticide | Per Cent Reduction After Treatment: House Flies 10 Minutes | House Flies 4 Hours | House Flies 24 Hours | Blow Flies 10 Minutes | Blow Flies 4 Hours | Blow Flies 24 Hours |
|---|---|---|---|---|---|---|
| Malathion (2%) | 78 | 89 | 80 | 85 | 80 | 79 |
| Bayer L 13/59 (2%) | 99 | 99 | 92 | 78 | 96 | 74 |
| Chlorthion (2%) | 91 | 95 | 88 | 75 | 83 | 73 |
| Shell OS 1808 (1%) | 95 | 98 | 83 | 84 | 83 | 71 |

triplicate with single applications on different dumps. The results are given in table 5.

There was no consistent difference in the effectiveness of the four insecticides against blow flies, but against house flies Bayer L 13/59 was consistently slightly more effective than the other materials. All insecticides gave sufficient kills of both species in a single treatment to indicate that good control could be obtained with repeated daily applications. In general, the results of all the tests indicate that liquid baits containing sweetening materials and suitable concentrations of insecticides are effective in controlling blow flies or combined populations of house flies and blow flies.

SUMMARY.—Shell OS 2046 (1-carbomethoxy-1-propen-2-yl dimethyl phosphate) and Shell OS 1808 (1-carbomethoxy-1-propen-2-yl diethyl phosphate) were more effective against blow flies, *Callitroga macellaria* (F.), than Bayer L 13/59 or Chlorthion when tested in malt baits at a concentration of 1 per cent at a rendering plant. On garbage and trash heaps in a substandard section of Orlando, Fla., malt bait containing 1 per cent of Chlorthion was highly effective against blow flies, principally *Phaenicia cuprina* (Wd.), after the fifth treatment.

In tests against house flies (*Musca domestica* L.) and blow flies (principally *Callitroga macellaria*) on garbage dumps malt baits containing 1 per cent of Shell OS 2046 or Shell OS 1808 or 2 per cent of malathion were the most effective, followed by 0.2 per cent of Bayer L 13/59 in sugar solution and 2 per cent of malathion in blackstrap molasses. After 24 hours baits containing 2 per cent of malathion and 50, 75, or 98 per cent of blackstrap molasses were more effective against both species than malathion baits containing 10 or 25 per cent of molasses, but the bait with 98 per cent was too thick for easy application. Baits containing 1 per cent of Shell OS 1808 or 2 per cent of Bayer L 13/59, Chlorthion, or malathion and 50 per cent of blackstrap molasses were about equally effective against blow flies, but the L 13/59 bait was slightly more effective than the others against house flies.

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# Evaluations of Some New Insecticides against Lice on Livestock and Poultry[1]

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Many people consider lice the most easily controlled of all pests of livestock and poultry. However, regardless of this assumption, the losses attributable to lice throughout the country are tremendous. Snipes (1948) showed that lice-free cattle gained an average of 73 pounds more per head than untreated cattle under identical conditions over a period of 61 days. Edgar & King (1950) in Alabama studied the effect of one species of louse on egg production, weight gains, and food consumption of poultry, and concluded, "The difference in net income between louse-negative and louse-positive flocks could be 30 to 40 per cent. This could mean approximately 75 to 85 cents more per louse-negative bird." According to the Agriculture Research Service (1954), the losses caused by lice alone to all classes of livestock and poultry in the United States are estimated to be approximately 52 million dollars annually. Much of those losses can be averted through the use of more effective insecticides and improved application methods.

Preliminary evaluation tests and a few field trials with some of the new insecticides against lice on cattle, goats, and poultry were conducted at the Kerrville, Texas, laboratory during 1953 and 1954. Since these tests were conducted at different times, no direct comparison can be made between materials. The data presented herein should serve as a basis for additional, more complete investigations for lice control on livestock and poultry.

CATTLE LICE.—Before candidate insecticides are considered for field trials against cattle lice they are subjected to spot-treatment tests to give them a rapid evaluation as regards initial kill of lice and residual potential. Areas approximately 6 inches square having a heavy population of lice are marked off on the laboratory "louse bank" animal by means of hair clippers or scissors. Between each square a strip at least 2 inches wide is left to insure an adequate source of lice for reinfesting the treated spots. These spots are thoroughly wet with a candidate insecticide, diluted to the desired concentration, by daubing it on with cotton. Emulsion concentrates and wettable-powder formulations are equally adaptable for this type of test and no difference was noted in their effectiveness.

Mortality records are taken after 24 or 48 hours and the treated areas are examined at weekly intervals thereafter.

The results obtained in these tests with a number of insecticides against the short-nosed cattle louse, *Haematopinus eurysternus* (Nitz.), are shown in table 1. The "Weeks Effective" column shows the time before adult lice were observed in the treated area. In most tests nymphs were observed about a week before adults.

All the materials tested by this method gave good initial kill of lice at concentrations of 0.25% or above, and most of the phosphorus insecticides were effective at lower concentrations. The phosphorus insecticides did not exhibit as much residual effectiveness as DDT, toxaphene, and Strobane, at the same concentration.

**Table 1.—Spot-treatment tests with several insecticides against *Haematopinus eurysternus* on cattle.**

| Insecticide and Concentration (Per Cent) | | Per Cent Mortality in 24 or 48 Hours | Weeks Effective |
|---|---|---|---|
| Chlorinated hydrocarbons: | | | |
| DDT | 0.5 | 100 | 4 |
| | .25 | 100 | 3 |
| Toxaphene | .5 | 100 | 4 |
| Strobane | .5 | 100 | 4 |
| Organic phosphorus compounds: | | | |
| Malathion | 0.5 | 100 | 2 |
| | .05 | 100 | 1 |
| Parathion | .05 | 100 | 3 |
| | .01 | 100 | 3 |
| | .005 | 25 | 0 |
| Am. Cyanamid 4124 | .25 | 100 | 3 |
| Chlorthion | .25 | 100 | 1 |
| Bayer L 13/59 | .25 | 100 | 1 |
| | .1 | 100 | 0 |
| Bayer 21/199 | .25 | 100 | 2 |
| | .2 | 100 | 2 |
| | .1 | 100 | 1 |
| | .05 | 100 | 1 |
| Diazinon | .25 | 100 | 2 |
| | .1 | 100 | 2 |
| | .05 | 100 | 1 |
| | .01 | 95 | 1 |
| | .005 | 25 | 1 |
| | .002 | 5 | 1 |
| Pirazinon | .25 | 100 | 3 |
| EPN | .05 | 100 | 1 |
| | .01 | 100 | 1 |
| | .005 | 100 | 1 |
| | .002 | 25 | 0 |
| NPD | .05 | 100 | 1 |
| 2-Pivalyl indandione | 1.0 | 100 | 3 |
| | .5 | 100 | 2 |
| | .25 | 100 | 2 |
| | .1 | 100 | 2 |
| | .05 | 100 | 2 |

Of the materials subjected to spot-treatment tests opportunity was afforded to initiate field trials with only Strobane. Heptachlor was included in the field trials because of its similarity to chlordane. Strobane was tested at 0.5 per cent and heptachlor at 0.5, 0.1, and 0.05 per cent against the long-nosed cattle louse, *Linognathus vituli* (L.). Both materials were applied in wettable-powder sprays. No live lice were observed on any of the treated animals when examined 24 and 48 hours and weekly for 4 weeks after treatment. These results indicate that Strobane and heptachlor are about equal in effectiveness to DDT, toxaphene, and chlordane.

GOAT LICE.—Preliminary evaluations against goat lice, primarily *Bovicola caprae* (Gurlt) and *limbatus* (Gerv.), are made by dipping infested animals in various concentrations of the insecticide. Ordinarily five goats

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are dipped in each concentration. After treatment the goats are placed in isolation pens, where they are maintained throughout the observation period. Mortality records are taken 24 and 48 hours after dipping and at intervals for approximately 4 or 5 weeks. The isolation pens are so arranged that the animals of one treatment are unable to come in contact with those of any other.

The results of these tests are shown in table 2. All materials, at each concentration tested, gave good initial kill except Bayer 21/200, but this material was used at extremely low concentrations. Most of the materials showed considerable residual effectiveness at all concentrations tested. This residual effectiveness was not evident in tests against the long-nosed cattle louse.

Four materials were tested against goat lice in field trials—EPN, one flock of 200 goats at 0.03 per cent; malathion, one flock of 300 goats at 0.5 per cent; Strobane, two flocks, one of 80 and one of 700 goats, at 0.5 per cent; and heptachlor, one flock of 450 goats at 0.25 per cent. Each flock was treated immediately after the goats had been shorn. The insecticide was applied with a sprayer operated at 300 pounds' pressure. Approximately 1 quart of spray material was required to wet each goat thoroughly. The EPN and Strobane sprays were prepared from wettable powders and malathion and heptachlor from emulsifiable concentrates.

Each material killed all the lice within 24 hours. The goats were not examined again until the next shearing, approximately 6 months after treatment. At that time no live lice were observed in either flock treated with Strobane. The flocks treated with malathion and heptachlor carried light infestations, and the EPN-treated flock a moderate infestation. The results of these field trials indicate that Strobane compares favorably with DDT, toxaphene, and chlordane for goat lice control, heptachlor and malathion are slightly less effective, and EPN is definitely inferior.

Table 2.—Tests with goats dipped in several insecticides for control of *Bovicola caprae* and *limbatus*.

| Insecticide and Concentration (Per Cent) | | Per Cent Mortality in 24 or 48 Hours | Infestation After 4 Weeks |
|---|---|---|---|
| Chlorinated hydrocarbons: | | | |
| DDT | 0.25 | 100 | None |
| Strobane | .2 | 100 | do |
| | .1 | 100 | do |
| Endrin | .05 | 100 | do |
| Isodrin | .05 | 100 | do |
| Organic phosphorus compounds: | | | |
| Malathion | .25 | 100 | do |
| | .1 | 100 | do |
| | .05 | 100 | do |
| | .025 | 100 | do |
| Diazinon | .05 | 100 | do |
| | .025 | 100 | do |
| | .05 | 100 | do |
| | .005 | 100 | Light |
| Chlorthion | .002 | 100 | None |
| Bayer L 13/59 | .1 | 100 | Light |
| | .05 | 100 | do |
| | .025 | 100 | do |
| | .01 | 100 | do |
| | .002 | 100 | do |
| Bayer 21/199 | .002 | 100 | None |
| Bayer 21/200 | .002 | 25 | Light |
| EPN | .002 | 100 | None |

POULTRY LICE.—DDT (5 or 10 per cent) and sodium fluoride dusts have been used for a number of years to control lice on poultry. To compare the effectiveness of several phosphorus and chlorinated hydrocarbon dusts with DDT, fowls carrying infestations of the chicken body louse, *Eomenacanthus stramineus* (Nitz.), were treated by the shaker can method.

The fowls used in the test were "culls" from local commercial flocks, primarily of New Hampshire Red and White Leghorn breeds. Louse infestations ranged from light to heavy on individual birds.

The dusts were prepared by diluting wettable powders with kaolin. Lindane, malathion, and Diazinon were diluted to 1 per cent, and the other materials to 5 per cent. Special effort was made to distribute the dust over each bird, particularly under the wings, along the thighs and on the neck, back, and vent. The average number of grams of each dust per bird is shown below:

| *Dusts* | *Grams* |
|---|---|
| DDT | 2.3 |
| Toxaphene | 2.4 |
| Strobane | 3.8 |
| Chlordane | 3.8 |
| Methoxychlor | 4.5 |
| TDE | 5.0 |
| Lindane | 4.5 |
| Malathion | 6.0 |
| Diazinon | 5.6 |

Each bird was examined 24 and 48 hours after treatment and at weekly intervals thereafter for 4 weeks. All the dusts gave complete control of the original infestation. However a few of the birds treated with methoxychlor, lindane, malathion, and Diazinon developed light reinfestations in 2 to 4 weeks, but otherwise the treatments were effective throughout the observation period.

DISCUSSION OF RESULTS.—The results obtained in these tests indicate that some of the new chlorinated hydrocarbon and phosphorus insecticides may be useful for the control of several species of lice affecting livestock and poultry. Most of the materials tested gave complete control of the louse infestations, except at the lower concentrations. Strobane was equally as effective as DDT, toxaphene, and chlordane. Of the phosphorus compounds tested, malathion and Diazinon showed considerable promise for this purpose. Several of the compounds were not tested thoroughly because of insufficient quantities. Other compounds may be found just as promising as those mentioned. At no time during these studies were toxic symptoms noted in the animals or poultry. However, further investigations are necessary to determine their complete safety as well as the minimum effective concentration for controlling lice.

SUMMARY.—In 1953 and 1954 preliminary tests were conducted with some of the new chlorinated hydrocarbon and phosphorus insecticides to determine their effectiveness in controlling lice on livestock and poultry. Most of the materials tested were effective against several species of lice. In general, the phosphorus compounds did not exhibit the residual effectiveness of the chlorinated hydrocarbons, but they were effective at much lower concentrations.

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# Methods of Treating Sorghum Selfing Bags for Insect Control[1]

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Sorghum is usually 5 to 6 per cent cross-pollinated. Therefore, in order to insure pure seed stock, some means of isolation must be used. The usual method of obtaining self-pollination is to cover the heads with paper bags (Fig. 1) just before flowering. The heads at this stage have a high moisture content, and the warm, humid conditions that develop within the bags are ideal for the corn earworm (*Heliothis armigera* (Hbn.)), the corn leaf aphid (*Rhopalosiphum maidis* Fitch), and various fungi. The bags also prevent parasites and predators from attacking earworms and aphids. As a result the insect damage is often so severe that the grain in entirely destroyed (Fig. 2).

Quinby & Gaines (1942) reported that the corn earworm destroyed approximately 75 per cent of the grain in bagged sorghum heads at Chillicothe, Texas. Hayes (1922) found that corn leaf aphids feeding on sorghum heads caused shriveled grain that germinated poorly. Dahms *et al.* (1951) made a preliminary report on the use of aldrin-treated bags for protecting sorghum heads from corn earworms and corn leaf aphids.

The problem of insect infestation in the sorghum heads became more important when several States required that all registered sorghum seed, and in some States certified seed as well, must be from bagged heads. Since all heads must be bagged in the research phase of the hybrid sorghum seed development program, insect infestations in the head were a hindrance in the advancement of this program (Stephens *et al.* 1952). From 1948 to 1952 tests were conducted at Stillwater, Oklahoma, to develop methods to prevent this insect damage to sorghum seed.

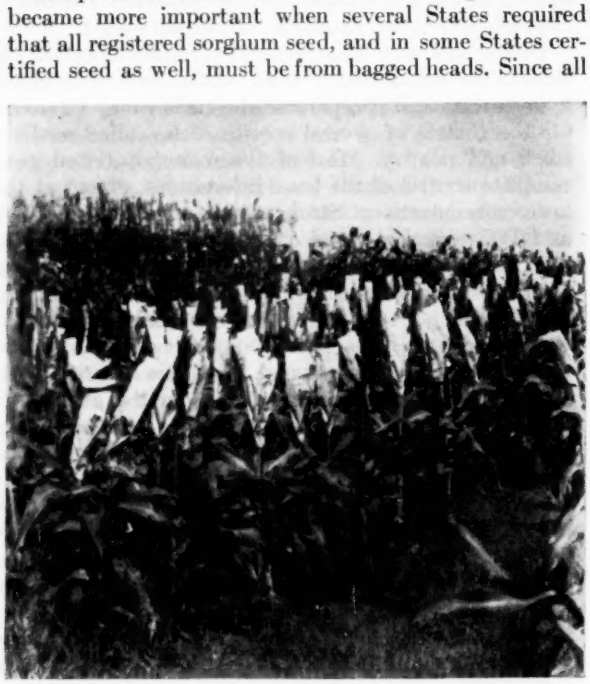

FIG. 1.—Selfing bags on sorghum heads.

MATERIALS AND METHODS.—The following methods of applying insecticides for the control of these insects were tested: Dusting the sorghum heads, dusting the inside of the bags, spraying the sorghum heads, impregnating the bags, and streaking the inside of the bags. Insecticides tested by one or more of these methods were aldrin, DDT, lindane, toxaphene, parathion, dieldrin, Metacide, Dilan, heptachlor, TEPP, BHC, chlordane, and demeton. Since insecticides that gave only aphid or earworm control were combined to make a treatment that would control both insects. The combinations were toxaphene plus BHC, DDT plus BHC, DDT plus TEPP, DDT plus lindane, toxaphene plus lindane, DDT plus Metacide, and toxaphene plus Metacide.

The spraying and dusting of sorghum heads or of paper bags were done with hand equipment just before the heads were bagged. The bags were impregnated by soaking them in an emulsion until saturated and then allowed to dry. Most of the bags were used as soon as they dried, but in 1950 some were not used for 6 months after treatment. Emulsifiable concentrates were applied with a brush as a streak on the inside of bags, and such bags were used within 60 days. A camel's-hair brush ½-inch in diameter was used, and a 3- to 4-inch streak was usually required to apply the desired amount of insecticide.

Special bags made of 50-substance, wet-strength, kraft paper with dimensions similar to 1-quart liquor sacks but having a pinched bottom were used except in the early exploratory tests in 1948, when conventional 6-pound paper sacks were used. The bags were made specifically for selfing sorghum, and the seams were sealed with a special waterproof glue.

At least 20 sorghum heads were included in each treatment, and any treatments that showed promise were retested on several hundred bags. Each treatment was tested on several varieties of sorghum. The bags were placed over the heads just prior to blooming and fastened tightly around the peduncle with a stapler. All bagging was done during July and August, when the maximum shade air temperature was often 100° F. or above.

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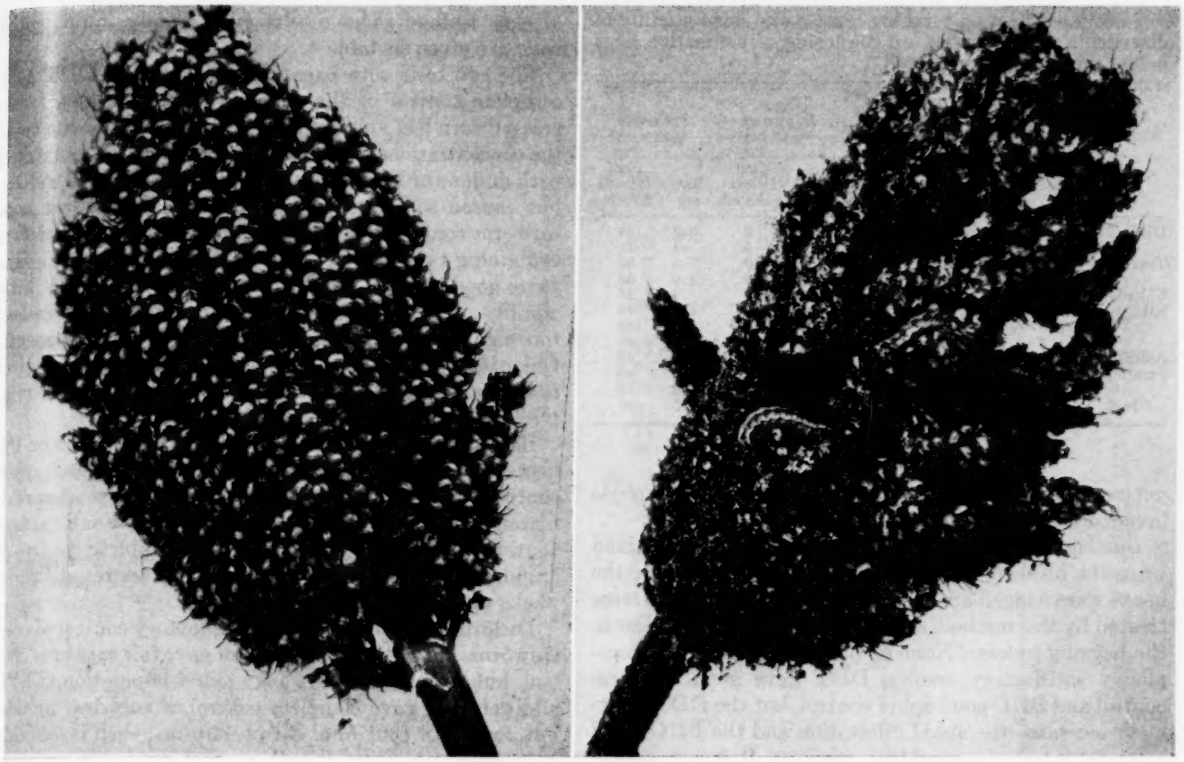

FIG. 2.—Heads of Texas milo: Head at left was bagged with a sack that had been impregnated with 0.5% aldrin. Head at right was bagged at the same time with an untreated sack.

The bags remained on the sorgham heads until the grain was mature. The length of this period depended on the variety and growing season, but was usually between 35 and 50 days. Each head was examined when harvested and rated for sterility and corn leaf aphid and earworm infestations on the following basis:

| *Rating* | *Sterility* | *Corn Leaf Aphids* | *Corn Earworms* |
|---|---|---|---|
| 0 | None | None, no exuviae | None, no frass |
| 1 | 5% or less on tip | 1–10 aphids or exuviae | 1 present or small amount of frass, less than 5% kernel damage |
| 2 | 6–20% | 10–50 aphids or exuviae | 1 present, moderate amount of frass, 6–20% kernel damage |
| 3 | 21–40% | 50–200 aphids or exuviae, some honeydew | 2 present, large amount of frass, 21–40% kernel damage |
| 4 | 41–80% | Aphids or exuviae throughout the head, much honeydew | More than 2 present, large amount of frass, 41–80% kernel damage |
| 5 | Above 80% | Head a solid mass of aphids, exuviae, and honeydew | More than 2 present, large amount of frass, more than 80% kernel damage |

For each test the number of heads in each class was multiplied by the rating. The products for the different classes were then added and divided by the number of heads to obtain mean infestation or a sterility rating. Any head that did not have a "0" rating was considered infested. Any head that showed 5 per cent or more of sterile florets was considered as showing some sterility.

RESULTS.—*Dusting the sorghum heads.*—The results obtained by applying the dusts directly to the sorghum heads before bagging are given in table 1. The rather high sterility in the check may have been due to the severe corn earworm injury. BHC caused high sterility, and both chlordane and parathion caused considerable sterility. Half of the heads treated with parathion were infested with corn leaf aphids. However, the heads were

**Table 1.—Effect on sorghum insects and head sterility of insecticide dusts applied to the heads before bagging.**

| Insecticide (Per Cent) | Toxicant per Head (mg.) | Corn Leaf Aphid | | Corn Earworm | | Sterility | |
|---|---|---|---|---|---|---|---|
| | | Rating | Per Cent Heads Infested | Rating | Per Cent Heads Infested | Rating | Per Cent Heads Affected |
| DDT 10 | 200 | 0.6 | 20 | 0.1 | 5 | 0.6 | 30 |
| Toxaphene 20 | 400 | .5 | 32 | .3 | 21 | .3 | 21 |
| Chlordane 10 | 200 | .2 | 15 | .2 | 10 | 1.2 | 74 |
| BHC (gamma isomer) 5 | 100 | .1 | 5 | 0 | 0 | 3.2 | 100 |
| Aldrin 2.5 | 50 | 0 | 0 | 0 | 0 | .2 | 5 |
| Parathion 2 | 40 | 1.0 | 50 | 0 | 0 | .8 | 55 |
| Check | 0 | 2.6 | 48 | 3.9 | 90 | 1.7 | 55 |

**Table 2.—Effect on sorghum insects and head sterility of insecticide dusts applied on the inside of pollination bags before the heads were bagged.**

| Insecticide (Per Cent) | Toxicant per Bag (mg.) | Corn Leaf Aphid | | Corn Earworm | | Sterility | |
|---|---|---|---|---|---|---|---|
| | | Rating | Per Cent Heads Infested | Rating | Per Cent Heads Infested | Rating | Per Cent Heads Affected |
| DDT 5 | 100 | 3.0 | 100 | 0.1 | 8 | 0.7 | 54 |
| 10 | 200 | 2.7 | 95 | .1 | 5 | .4 | 21 |
| Toxaphene 10 | 200 | 1.7 | 88 | 1.1 | 40 | .5 | 36 |
| 20 | 400 | 1.9 | 64 | .5 | 33 | 1.0 | 56 |
| Chlordane 10 | 200 | 1.2 | 45 | .7 | 49 | .7 | 45 |
| BHC (gamma 1 | 20 | .1 | 9 | 2.0 | 80 | 1.6 | 72 |
| isomer) 3 | 60 | .2 | 18 | 1.4 | 90 | 2.0 | 63 |
| 5 | 100 | 0 | 0 | .4 | 37 | 2.9 | 64 |
| Aldrin 2.5 | 50 | 1.2 | 90 | .9 | 72 | 1.1 | 63 |
| Parathion 1 | 20 | .6 | 45 | .8 | 45 | .8 | 45 |
| 2 | 40 | .9 | 75 | .4 | 25 | .2 | 10 |
| Check | 0 | 2.0 | 59 | 2.9 | 86 | 1.7 | 60 |

not severely damaged, and it is likely that the aphids invaded them some time after they were bagged.

*Dusting the inside of the bags.*—The results obtained when the inside of the selfing bags was dusted before the heads were bagged are shown in table 2. When bags were treated by this method, some of the insecticide was lost in the bagging process. None of the insecticides gave completely satisfactory results. DDT gave good earworm control and BHC good aphid control, but the DDT treatment increased the aphid infestation and the BHC at all three rates tested caused high sterility. It is not known why aldrin gave good control when applied to the head but not when applied to the inside of the selfing bags.

*Spraying the sorghum heads.*—Since spraying the heads required more labor and time than other treatments, this method would not be practical from the sorghum breeders' standpoint. Therefore, only a few insecticides were tested by this method. The insecticides used and results are shown in table 3. This method affected sterility less than the other methods, possibly because the total toxicant used per head was less in most cases. All the insecticides except chlordane caused a reduction in the percentage of heads infested with corn leaf aphids. TEPP, BHC, demeton, and chlordane were ineffective against the corn earworm. Aldrin and the DDT-TEPP combination gave complete control of both insects.

*Impregnation of the bags.*—Since impregnation of selfing bags would require less time and the bags could be prepared in advance, most of the tests were made of this method. The results with freshly impregnated bags are given in table 4.

**Table 3.—Effect on sorghum insects and head sterility of insecticide sprays applied to the head before bagging.**

| Insecticide (Per Cent) | Toxicant per Head (mg.) | Corn Leaf Aphid | | Corn Earworm | | Sterility | |
|---|---|---|---|---|---|---|---|
| | | Rating | Per Cent Heads Infested | Rating | Per Cent Heads Infested | Rating | Per Cent Heads Affected |
| DDT 0.11 | 44 | 0.8 | 35 | 0.1 | 12 | 0.1 | 12 |
| DDT 0.5+TEPP 0.05 | 200+20 | 0 | 0 | 0 | 0 | .1 | 10 |
| Toxaphene 0.23 | 92 | .5 | 24 | .5 | 34 | .4 | 29 |
| Chlordane 0.11 | 44 | 1.4 | 65 | 1.3 | 60 | .4 | 25 |
| BHC (gamma 0.013 isomer) | 5 | .1 | 5 | 2.2 | 85 | .7 | 30 |
| Aldrin 0.02 | 8 | 0 | 0 | 0 | 0 | 0 | 0 |
| Parathion 0.05 | 20 | .7 | 32 | .7 | 32 | .3 | 21 |
| TEPP 0.1 | 40 | 0 | 0 | 2.7 | 86 | .5 | 34 |
| Demeton 0.1 | 40 | 0 | 0 | 2.6 | 100 | .2 | 23 |
| Check | 0 | 1.7 | 57 | 3.1 | 90 | 2.0 | 80 |

The two tests with bags impregnated with DDT gave complete control of the corn earworm, but greatly increased corn leaf aphid injury. Toxaphene at about twice the concentrations was comparable to DDT. Bags treated with lindane or BHC gave fair control of corn leaf aphids, but caused some sterility. Lindane gave excellent corn earworm control, but BHC was not effective. A mixture containing 1 per cent of DDT and 0.25 per cent of lindane gave good control of both insects and caused little sterility. All the toxaphene-lindane formulations caused too high sterility to be used in selfing-bag treatments. Chlordane-treated bags were not satisficatory for control of either insect and caused high sterility even at a relatively low concentration.

Bags impregnated with 0.5% aldrin or with 0.5 or 1% heptachlor gave excellent earworm control, good aphid control, and caused practically no sterility. Approximately 150 mg. per bag was required to give satisfactory control. This treatment did not give complete control of aphids, but the aphid infestation did not occur until 2 to 3 weeks after the heads were bagged.

Dieldrin and Metacide gave satisfactory control of corn earworms but not of aphids. Dilan gave fair earworm control, but permitted a very high aphid population. TEPP and demeton gave complete control of corn leaf aphids, but very poor control of corn earworms; each insecticide caused some sterility. Parathion gave good corn earworm control, but only fair corn leaf aphid control.

*Delayed use of impregnated bags.*—The results of the tests with selfing bags approximately 6 months after they had been impregnated with insecticides are given in table 5. By comparing the results in tables 4 and 5, it can be seen that there is little loss in toxicity due to delayed use. Since these tests were made, bags impregnated with 0.5% aldrin have been found to be effective after 24 months.

*Streaking the inside of the bags.*—The only insecticide used by the streak method was aldrin. A comparison of this method of applying and impregnation is given in table 6. The streak method gave better control when the insecticide was used at the same rate per bag. Even the low dosage of 72 mg. per bag gave satisfactory corn earworm control.

Since aldrin-impregnated bags gave satisfactory results in the field, sorghum breeders in Oklahoma and Texas treated several hundred thousand bags during the 1951 and 1952 seasons. However, some difficulty was encountered in drying the bags when they were treated in large bundles, and in 1953 most of the breeders changed to the streak method.

SUMMARY.—The use of paper bags on sorghum heads to insure self-fertilization creates an ideal environment for the corn leaf aphid, *Rhopalosiphum maidis Fitch*, and the corn earworm, *Heliothis armigera* (Hbn.). Several insecticides and methods of application for reducing the damage were tested. Some insecticides gave satisfactory control when the selfing bags were dusted on the inside or when the heads were dusted or sprayed just before bagging. However, since these methods were not practical, most of the tests were made by impregnating the bags with emulsions.

DDT, when impregnated at the rate of 133 mg. or

**Table 4.—Effect on sorghum insects and head sterility of insecticides used to impregnate selfing bags.**

| Insecticide (Per Cent) | Toxicant per Bag (mg.) | Corn Leaf Aphid | | Corn Earworm | | Sterility | |
|---|---|---|---|---|---|---|---|
| | | Rating | Per Cent Heads Infested | Rating | Per Cent Heads Infested | Rating | Per Cent Heads Affected |
| DDT 0.1 | 25 | 1.1 | 42 | 0.9 | 69 | 0.3 | 21 |
| .5 | 133 | 2.7 | 82 | 0 | 0 | .1 | 7 |
| 1.0 | 250 | 3.2 | 92 | 0 | 0 | .2 | 14 |
| DDT 1.0+BHC 0.25[a] | 250+63 | .8 | 58 | 0 | 0 | .1 | 8 |
| DDT 1.0+lindane 0.25 | 290+72 | .1 | 7 | 0 | 0 | .2 | 17 |
| 1.0+lindane 0.5 | 315+158 | .1 | 3 | 0 | 0 | .7 | 41 |
| .5+lindane 0.25 | 146+73 | .3 | 20 | 0 | 0 | .2 | 13 |
| .5+lindane 0.5 | 147+147 | .2 | 17 | 0 | 0 | .7 | 37 |
| DDT 0.5+Metacide 0.5 | 172+172 | 1.3 | 45 | 0 | 0 | .2 | 17 |
| Toxaphene 0.25 | 73 | 1.9 | 67 | 2.0 | 77 | .1 | 10 |
| .5 | 135 | 1.2 | 59 | 1.4 | 60 | .2 | 14 |
| 1.0 | 290 | 1.6 | 70 | .1 | 4 | .1 | 7 |
| 1.5 | 432 | 1.4 | 54 | .1 | 4 | .2 | 18 |
| 2.0 | 570 | 1.1 | 61 | .1 | 11 | .1 | 11 |
| Toxaphene 2.0+BHC 0.25[a] | 604+76 | 0 | 0 | .2 | 17 | .1 | 8 |
| Toxaphene 2.0+lindane 0.25 | 670+84 | .2 | 17 | .1 | 3 | .7 | 40 |
| 2.0+lindane 0.5 | 704+176 | .1 | 10 | 0 | 0 | 2.3 | 90 |
| 1.5+lindane 0.25 | 442+74 | .1 | 4 | 0 | 0 | 1.0 | 50 |
| Toxaphene 1.5+Metacide 0.5 | 505+168 | .5 | 24 | .1 | 3 | .1 | 7 |
| Chlordane 0.25 | 70 | 1.8 | 70 | 2.1 | 90 | 1.3 | 45 |
| Heptachlor 1.0 | 301 | .1 | 12 | 0 | 0 | .1 | 12 |
| .5 | 153 | .5 | 27 | .1 | 2 | .1 | 5 |
| Dilan 1.0 | 316 | 4.1 | 90 | .4 | 17 | .1 | 11 |
| .5 | 155 | 3.8 | 97 | .3 | 23 | .1 | 3 |
| Dieldrin 0.25 | 68 | .8 | 48 | 0 | 0 | .1 | 4 |
| .1 | 25 | 1.4 | 70 | 0 | 0 | .1 | 4 |
| Aldrin 0.5 | 151 | .4 | 19 | .1 | 4 | .2 | 14 |
| .25 | 74 | 1.2 | 46 | .1 | 4 | .1 | 7 |
| .1 | 29 | 1.4 | 76 | .1 | 3 | .1 | 10 |
| BHC 0.5[a] | 125 | 0 | 0 | .3 | 17 | .7 | 28 |
| .1[a] | 25 | .1 | 8 | 2.1 | 83 | .8 | 50 |
| .025[a] | 6 | .4 | 25 | 3.1 | 91 | 1.8 | 75 |
| Lindane 0.5 | 147 | .5 | 10 | 0 | 0 | .8 | 52 |
| .25 | 69 | .2 | 15 | 0 | 0 | .7 | 47 |
| Parathion 1.0 | 317 | .5 | 34 | 0 | 0 | .2 | 19 |
| .5 | 145 | .4 | 25 | .1 | 8 | .2 | 17 |
| TEPP 0.1 | 25 | 0 | 0 | 2.2 | 96 | .5 | 29 |
| Demeton 0.25 | 69 | 0 | 0 | 2.6 | 100 | .4 | 23 |
| Metacide 1.0 | 345 | .9 | 41 | .2 | 13 | .3 | 28 |
| .5 | 165 | 1.1 | 39 | 0 | 0 | .5 | 32 |
| .25 | 81 | 1.2 | 50 | .2 | 10 | .3 | 17 |
| Check | 0 | 1.6 | 58 | 3.7 | 95 | 1.1 | 41 |

[a] Gamma isomer

above per bag, gave excellent control of the corn earworm, but caused an increase in corn leaf aphids. Heptachlor, aldrin, dieldrin, lindane, and Metacide also gave good corn earworm control. Toxaphene gave satisfactory corn earworm control when applied at 290 mg. or above per bag. BHC, lindane, heptachlor, aldrin, TEPP, and demeton gave satisfactory corn leaf aphid control; however, both BHC and lindane caused a high sterility. Aldrin and heptachlor gave satisfactory control of both insects and caused little sterility.

Aldrin gave fair control of the corn leaf aphid and excellent control of the corn earworm when applied as a streak on the inside of the bags at 72 mg. per bag.

**Table 5.—Effect on sorghum insects and head sterility of insecticide impregnated selfing bags used 6 months after treatment.**

| Insecticide (Per Cent) | Toxicant per Bag (mg.) | Corn Leaf Aphid | | Corn Earworm | | Sterility | |
|---|---|---|---|---|---|---|---|
| | | Rating | Per Cent Heads Infested | Rating | Per Cent Heads Infested | Rating | Per Cent Heads Affected |
| DDT 1.0 | 222 | 3.1 | 81 | 0 | 0 | 0.7 | 22 |
| DDT 1.0+lindane 0.25 | 273+68 | 0 | 0 | 0 | 0 | .4 | 18 |
| Toxaphene 2.0 | 594 | 0.7 | 28 | 0.1 | 7 | .6 | 29 |
| Toxaphene 2.0+lindane 0.25 | 508+63 | .1 | 10 | .1 | 10 | .5 | 40 |
| Dieldrin 0.5 | 136 | 1.3 | 41 | 0 | 0 | .6 | 24 |
| Aldrin 0.5 | 139 | .2 | 16 | 0 | 0 | .5 | 30 |
| Lindane 0.5 | 137 | .1 | 10 | 0 | 0 | 1.7 | 75 |
| 0.25 | 49 | .1 | 13 | .1 | 3 | .2 | 20 |
| Parathion 1.0 | 262 | .4 | 31 | .1 | 3 | .4 | 21 |
| Metacide 1.0 | 325 | 1.9 | 63 | .1 | 4 | .8 | 41 |
| Check | 0 | 3.3 | 89 | 3.8 | 95 | .4 | 30 |

**Table 6.—A comparison of the streaking and impregnation methods of treating sorghum selfing bags with aldrin.**

| Treatment | Per Cent Aldrin Concentration | Toxicant per Bag (mg.) | Corn Leaf Aphid | | Corn Earworm | | Sterility | |
|---|---|---|---|---|---|---|---|---|
| | | | Rating | Per Cent Heads Infested | Rating | Per Cent Heads Infested | Rating | Per Cent Heads Affected |
| Streaked | 24 | 72 | 1.8 | 76 | 0.1 | 4 | 0.6 | 44 |
| | | 144 | .2 | 16 | .1 | 5 | .2 | 12 |
| Impregnated | 0.5 | 144 | .8 | 31 | .2 | 13 | .3 | 23 |
| Check | — | 0 | 4.1 | 95 | 1.4 | 67 | 2.3 | 77 |

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# The Toxicity of Five Organic Insecticides to Resistant and Non-Resistant Strains of *Blattella germanica* (L.)[1]

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Summaries of previous work concerning insects resistant to insecticides have been prepared by Babers (1949) and Babers & Pratt (1951). Heal *et al.* (1953) reported that a strain of German cockroaches found at Corpus Christi, Texas, were highly resistant to chlordane. Stock from the original strain, discovered at Corpus Christi, Texas, was obtained from the Velsicol Corporation, Chicago, Illinois. Since establishing the culture no attempt has been made to increase the degree of resistance by subjecting the cockroaches to insecticidally treated surfaces, although during the earlier generations some adult females that survived toxicological tests with chlorinated hydrocarbon compounds were returned to the breeding cage.

PROCEDURE.—These studies were made to determine the relative toxicities of chemically pure aldrin, chlordane, dieldrin, heptachlor, and lindane to the chlordane-resistant strain in comparison with a normal strain of German cockroaches. All chemicals used, with the exception of lindane, were supplied by the Velsicol Corporation. The lindane sample was furnished by the Pennsylvania Salt Manufacturing Co. Both strains of cockroaches were reared in such a manner that individuals of known age were available for testing.

The method of application used was that of microinjection. The chief value of this method is that, unlike other techniques, a known amount of toxicant is introduced directly into the body cavity of the insect.

The technique employed was the same as that described by Lea (1950). The injection apparatus consisted of a Yale B.D. tuberculin syringe clamped on a wooden base $9\frac{1}{2}$ inches long and $4\frac{1}{4}$ inches wide. The syringe was fitted with a 26-gauge stainless steel needle and aligned so that the plunger could be advanced by a Lufkin micrometer which was also mounted on the wooden base. A small magnifying lens held by a universal clamp on a bolt set upright in the wooden base was adjusted to give an enlarged image of the micrometer scale, thereby insuring more accurate manipulation (Fig. 1).

Adult non-capsulated female cockroaches (McGovran & Fales 1950) 1 to 2 weeks old were selected for injection by random removal from the rearing jars with an aspirator. The bottles used with the aspirator were padded with cellucotton to minimize the danger of mechanical injury to the cockroaches. The selected individuals were anesthetized by exposure to a constant stream of carbon dioxide and then placed on a holding apparatus which consisted of a Büchner funnel covered with a piece of cheesecloth and connected to the outlet valve of a cylinder of carbon dioxide. The valve was adjusted to release just enough carbon dioxide to keep the cockroaches immobilized on the cheesecloth (Williams 1946).

Preliminary evaluation of random samples of unweighed individuals showed a wide range of mortalities in repetitive tests. It was thought that these inconsistencies were influenced by the variation in body weights of the female cockroaches. To prove this many anesthetized female cockroaches were weighed, grouped into three weight ranges, and injected with 2.05 microliters of the solvent, which consisted of 80 per cent deobase, 10 per cent acetone, and 10 per cent xylene. The results indicated a direct relationship between body weight and mortality. From these results it was concluded that the cockroaches used for this evaluation should be within the weight range of 70 to 100 milligrams.

Prior to injecting the weighed cockroaches were placed in glass bottles 2 inches in diameter and 4 inches in height and held for a period of 12 hours in an 80° F. constant temperature room, having a relative humidity of approximately 50 per cent and a constant light source. After this period they were again anesthetized. Each cockroach was transferred to the left hand and held with the ventral side up and the posterior end of the abdomen directed toward the injection apparatus. The needle was inserted in the intersegmental area between the fourth and fifth sternites, slightly to the left of the midventral line to a depth of nearly $\frac{3}{8}$ inch, care being exercised to keep the point parallel with the exoskeleton. The prescribed amount of toxicant was injected into the hemocoele of the cockroach by rotation of the micrometer. Each cockroach was left on the needle a few seconds to allow the toxicant to disperse. On removal the cockroaches were transferred to plastic holding cages supplied with food, water, and roost. These cages were returned to the constant temperature and humidity room where mortality records were made 24 and 48 hours later. The criterion for mortality was the inability of the cockroach to right itself when the bottom of the holding cage was vigorously tapped with a pencil. Ten cockroaches were confined in each cage and two replicates were used for each dosage

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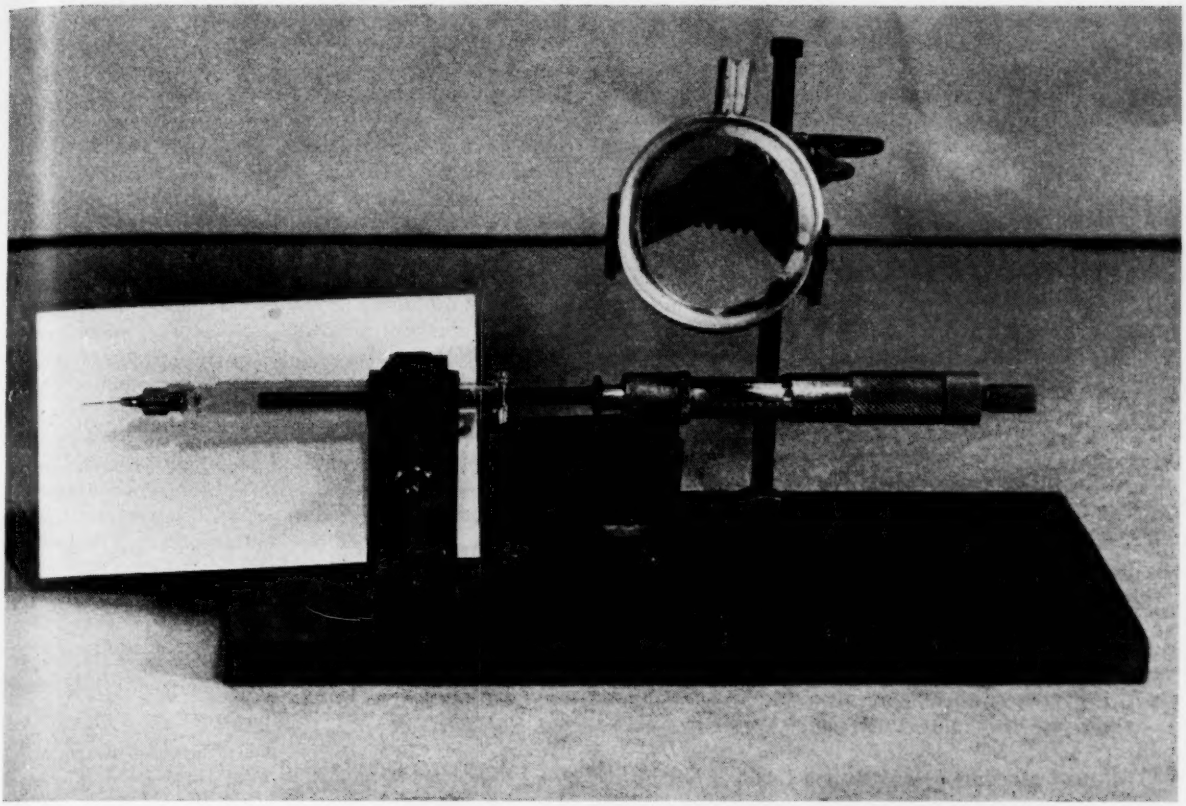

FIG. 1.—The microinjection apparatus. The index card is included for the purpose of sharper delineation of the needle.

level. Controls consisted of two replicates of cockroaches injected with the solvent alone.

The injection syringe was calibrated and each one-thousandth of an inch micrometer rotation delivered 20 micrograms of toxicant in 0.41 microliters of solution. The volume of solution injected into each insect was kept constant at 2.05 microliters. This was near the maximum amount of solvent that could be injected without causing some mortality.

DISCUSSION.—Some levels of mortality forming the points from which the log dosage/mortality curves were plotted did not lie within the limits generally considered to afford optimum accuracy. The higher points were included in order to give more accurate $LD_{90}$ values. It is believed that sufficient points have been included within the range between 35 and 85 per cent mortality (Bliss 1940). It was necessary, in a few cases, to arrive at the $LD_{90}$ values by extrapolation. The accuracy of such computation is not often of a high degree; however, this method was applied in order to derive a better understanding of the difference in slope which occurs in relation to curves derived from the study of both the resistant and normal strains. The $LD_{50}$ of an insecticide is of little actual value to the economic entomologist unless something is also known of the $LD_{90}$ or of the slope of the dosage/mortality curve. While some errors may have occurred, general adaptability of most of the points to curve-fitting was encountered throughout.

During the period in which these tests were conducted, the appearance of a few replicates that departed from the general pattern was noted. Although these instances were not numerous, they serve to demonstrate the fallacy of assuming that accurate data may be obtained readily from results of a single test without replication. Bliss (1940) recognizes the occurrence of such occasional departures and states that exclusion is desirable.

The data in table 1 indicates the resistant strain of cockroaches possesses resistance not only to chlordane but to all the other chemicals as well. The $LD_{50}$ values place the compounds in the following descending order of toxicity: lindane, dieldrin, heptachlor, aldrin, and chlordane. This sequence was obtained with normal cockroaches. The range in toxicity was found to be quite wide, lindane being approximately 80 times more toxic than chlordane at the $LD_{50}$ level and about 70 times more toxic at the $LD_{90}$. This sequence does not hold for the results with the re-

**Table 1.—Summary of $LD_{50}$ and $LD_{90}$ values[a] for normal and resistant strains.**

| COMPOUND | NORMAL STRAIN | | RESISTANT STRAIN | |
|---|---|---|---|---|
| | $LD_{50}$ | $LD_{90}$ | $LD_{50}$ | $LD_{90}$ |
| Aldrin | 26.46 | 70.06 | 127.61 | 1113.60 |
| Chlordane | 81.29 | 144.27 | 1117.50 | 4648.80 |
| Dieldrin | 6.59 | 17.35 | 68.37 | 502.49 |
| Heptachlor | 9.07 | 19.85 | 174.21 | 1509.30 |
| Lindane | 1.01 | 2.57 | 23.13 | 75.02 |

[a] These values are expressed in terms of micrograms of toxicant per gram of body weight.

sistant cockroaches, heptachlor exhibiting a lower toxicity than aldrin. The remaining insecticides appeared in the same order as indicated for normal cockroaches, and variation in relative toxicity was still evident but not as great, lindane being approximately 55 times more toxic than chlordane at the $LD_{50}$ level and about 60 times more toxic at $LD_{90}$.

The data in table 2 concerning the degree of resistance to the various compounds is of interest. According to the results compiled it appears that the resistant strain cockroaches are more resistant to heptachlor than to chlordane or any of the other compounds. These data indicate that the cockroaches exhibit about the same degree of resistance to chlordane, dieldrin, heptachlor, and lindane at the $LD_{50}$ level with aldrin showing a lesser value. It is apparent that the slope of the log-dosage/mortality curve for heptachlor has been lessened to such a degree that at $LD_{90}$ its effectiveness in relation to the other compounds has been reduced by approximately 2.5 to 5 times. The cockroaches exhibited the lowest relative degree of resistance to aldrin. However, the degree of resistance is a comparison of the relative toxicity of a compound to normal and resistant insects. It is not a direct means of comparing the effectiveness of two compounds. Although the degree of resistance of the resistant strain is lower in regard to aldrin than is the case with either dieldrin or lindane, it is obvious from the $LD_{50}$ and $LD_{90}$ values in table 2 that both of these compounds are more toxic to both strains of cockroaches than is aldrin.

The greater degree of resistance evident in regard to heptachlor as opposed to the other insecticides would be difficult to explain satisfactorily. It would not be unreasonable to conjecture that at some time the resistant strain might have come in contact with ample amounts of heptachlor. In much of the technical chlordane available, varying amount of heptachlor occur among the fraction of related compounds contained in the technical grade. Since heptachlor is one of the more volatile and probably the most toxic of these related compounds, it could be inferred that the cockroaches may well have been faced with a barrier of heptachlor before encountering chlordane. It would follow that resistance to chlordane might pre-suppose a high degree of resistance to heptachlor.

Table 2.—The degree of resistance determined by the formula[a] of Fisk & Isert (1953).

| Compound | Degree of Resistance | |
|---|---|---|
| | At $LD_{50}$ | At $LD_{90}$ |
| Aldrin | 4.82 | 15.89 |
| Chlordane | 13.76 | 32.22 |
| Dieldrin | 10.37 | 28.54 |
| Heptachlor | 19.21 | 76.04 |
| Lindane | 22.72 | 29.19 |

[a] $\text{Resistance} = \frac{LD_{50} \text{ of resistant strain}}{LD_{50} \text{ of normal strain}}$

The same equation was modified, using the $LD_{90}$ values as a further comparison.

Summary.—A strain of chlordane resistant German cockroaches, *Blattella germanica* (L)., and a strain of normal individuals of the same species were reared under similar conditions. Individuals of both strains were used in the evaluation of five insecticidal compounds: aldrin, chlordane, dieldrin, heptachlor and lindane. The insecticides were introduced into the hemocoele by a microinjection apparatus, using cockroaches of a specific weight range. The results with normal cockroaches show the compounds can be listed in order of descending toxicity as follows: lindane, dieldrin, heptachlor, aldrin, chlordane; with resistant cockroaches, lindane, dieldrin, aldrin, heptachlor, chlordane. The resistant strain of cockroaches showed some degree of resistance to all the compounds, but the highest degree of resistance was exhibited in relation to heptachlor.

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# Insecticides for Cherry Fruit Fly Control[1]

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There are two species of fruit flies that attack cherries in Erie County, Pennsylvania. These are the black cherry fruit fly, *Rhagoletis fausta* (O.S.), and the cherry fruit fly, *R. cingulata* (Loew). Since the habits of the two insects are similar they will be treated as a single species in this report. In Erie County the cherry fruit fly is the most important insect found on cherries and in recent years has been unusually destructive in some orchards. Although sprays of lead arsenate appear to give satisfactory control in many orchards, this program has not been entirely satisfactory in some plantings and has given little or no protection in residential plantings. In order to secure further information on some of the newer insecticides against the fruit fly, field experiments have been conducted in infested cherry orchards from 1952 through 1954. This report is a summary of the results.

METHODS AND MATERIALS.—All the test orchards were either isolated plantings or large blocks in orchards that were known to be infested with the insect. Since it is not desirable to leave untreated checks in sprayed orchards information on the degree of infestation was obtained by checking the test orchards the year before the experiments were carried out. This method gave some information on the infestation that normally would have developed in the absence of control measures.

The sprays were applied with a hydraulic sprayer and a standard orchard spray gun. All the spraying was done from the ground and from the outside of the tree. Previous to the time the maggots started to emerge from the fruit a sample of cherries was taken from the center row of trees in each plot. The cherries were counted and placed in trays which had $\frac{1}{4}$-inch galvanized hardware cloth bottoms. The trays were suspended over pans of water and any maggots leaving the fruit dropped into the water. A record was made of the number of maggots strained from the water.

The materials used in the experiments as shown in table 1 were commercially formulated products with lead arsenate used as a standard.

RESULTS OF FIELD EXPERIMENTS.—The tests were carried out in commercial orchards and in residential plantings that were known to be infested with fruit flies. Test numbers 6, 7 and 8 were conducted in a block of sweet cherries planted to the varieties Windsor and Napoleon. All the other experiments were carried out in sour cherry orchards planted to the variety Montmorency.

A list of the insecticides tested, dates of applications and the number of maggots per 100 fruits are given in table 1, together with the infestation of the previous year. A summary of the results of the tests against the immature forms (eggs and maggots) are given in table 2.

As may be noted in table 1, test No. 1, sprays of lead arsenate were not particularly effective against the fruit fly. The fruit was 1.6 per cent infested. In a residential planting, test No. 11, sprays of lead arsenate were also

**Table 1.—Effectiveness of various sprays for control of the cherry fruit fly as indicated by maggots found in harvested fruit, 1952–54.**

| TEST NO. | MATERIAL[a] AND POUNDS PER 100 GALLONS | DATE OF APPLICATIONS | MAGGOTS PER 100 FRUITS |
|---|---|---|---|
| 1 | Lead arsenate, 2 | June 16<br>June 24 | 1.6 |
| 2 | 15% parathion, 1.5 | June 16<br>June 24<br>July 3 | 0.5 |
| 3 | 25% EPN, 1 | June 16<br>June 24<br>July 3 | 0.6 |
| 4 | 25% dieldrin, 1 | June 16<br>June 24 | 0.8 |
| 5 | 25% dilan, 3 | June 16<br>June 24 | 3.4 |
| | Infestation 1951, 27.0 Per Cent | | |
| 6 | Lead arsenate, 2<br>15% parathion, 1.5 | June 15<br>June 25 | 0.6 |
| 7 | Lead arsenate, 2<br>25% malathion, 3 | June 15<br>June 25 | 0.3 |
| 8 | Lead arsenate, 2 | June 15 | 19.0 |
| | Infestation 1952, 26 Per Cent | | |
| 9 | Lead arsenate, 2<br>25% EPN, 1 | June 15<br>June 25<br>July 3 | 4.6 |
| 10 | Lead arsenate, 2<br>25% EPN, 1 | June 5<br>June 25 | 8.9 |
| 11 | Lead arsenate, 2 | June 15<br>June 25 | 42.3 |
| | Infestation 1952, 50 Per Cent | | |
| 12 | Lead arsenate, 2<br>25% malathion, 4 | June 15<br>June 23<br>July 1 | 1.1 |
| | Infestation 1953, 50 Per Cent | | |
| 13 | Lead arsenate, 2<br>25% malathion, 4 | June 15<br>June 23<br>July 1 | 4.2 |
| | Infestation 1953, 52 Per Cent | | |
| 14 | Lead arsenate, 2<br>25% diazinon, 2 | June 15<br>June 24<br>July 2 | 0.2 |
| 15 | Lead arsenate, 2<br>25% EPN, 1 | June 15<br>June 24<br>July 2 | 0.21 |
| 16 | Lead arsenate, 2<br>15% parathion, 1.5 | June 15<br>June 24<br>July 2 | 0.14 |
| | Infestation 1953, 20 Per Cent | | |

[a] All materials were wettable powders except arsenate of lead.

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of little value against the insect. The recommended schedule of one spray of lead arsenate spray on sweet cherries, test No. 8, did not give satisfactory control. The fruit was 19 per cent infested. The phosphate compounds, parathion, EPN, Diazinon and malathion, appear to be quite effective against the cherry fruit fly. Three applications of parathion or EPN gave excellent control of the cherry fruit fly. A split schedule of lead arsenate and malathion and lead arsenate and parathion (test Nos. 6 and 7) greatly reduced the fruit fly infestation in a sweet cherry orchard. A split schedule of lead arsenate and Diazinon (test No. 14) was quite effective against the fruit fly.

TESTS AGAINST THE IMMATURE STAGES.—During the seasons of 1953–1954 cherry orchards were treated with several phosphate compounds after the fruit was known to be infested with eggs and maggots. One application of spray was applied to the test trees. A sample of fruit was collected from the treated trees 1 day after the sprays were applied. The results of the tests are shown in table 2. Sprays of parathion, EPN and Diazinon were quite effective against the immature forms in the fruit. Although sprays of malathion greatly reduced the number of maggots that emerged from the fruit the results indicate that this material is less effective than parathion, EPN and Diazinon.

**Table 2.—Effectiveness of sprays for the control of immature stages of the cherry fruit fly as indicated by maggots found in the harvested fruit, 1953–54.**

| TEST NO. | MATERIAL AND POUNDS PER 100 GALLONS | DATE OF APPLICATION | MAGGOTS PER 100 FRUITS |
|---|---|---|---|
| 1 | 15% parathion, 1.5 | July 7 | 0.0 |
| 2 | 26% EPN, 1 | July 7 | 0.0 |
| 3 | 25% Diazinon, 2 | July 7 | 0.0 |
| 4 | 25% malathion, 3 | July 7 | 12.8 |
| 5 | Check, no spray (1953) | | 52.6 |
| 6 | 25% EPN, 1 | July 6 | 0.36 |
| 7 | 25% Diazinon, 2 | July 6 | 0.10 |
| 8 | 15% parathion, 1.5 | July 6 | 0.00 |
| 9 | 25% malathion, 4 | July 6 | 0.42 |
| 10 | Check (1954) no spray | | 20.00 |

**Table 3.—Effectiveness of soil treatments for control of cherry fruit fly as indicated by the emergence of adult flies.**

| MATERIALS AND POUNDS PER ACRE | NO. FLIES EMERGED | PER CENT REDUCTION |
|---|---|---|
| 40% chlordane, 25 | 322 | 56.4 |
| 50% dieldrin, 10 | 241 | 67.3 |
| Check, no treatment | 739 | |

SOIL EXPERIMENTS.—During the season of 1953 plots of soil were treated with chlordane and dieldrin. The insecticides were wettable powders and were mixed with water before they were applied to the soil. In these tests 1680 infested fruits were placed on 25 square feet of soil in each instance. The number of flies emerging from the soil is given in table 3. As may be noted chlordane and dieldrin reduced the number of flies that emerged from the treated soil. However, the reduction was not great and further work will be necessary to finally establish the value of soil treatments for cherry fruit fly control.

SUMMARY.—The results of the experiments indicate that parathion, EPN and Diazinon are quite effective against the cherry fruit fly. A split schedule of lead arsenate in the first maggot spray followed by two applications of either parathion, Diazinon or EPN at weekly intervals gave excellent control of the fruit fly. In residential plantings lead arsenate was of little value against the insect. Sprays of malathion were not as effective as parathion in reducing severe infestations of the cherry fruit fly.

Sprays of parathion, EPN, Diazinon and malathion appear to be quite effective against the immature stages in the fruit. Preliminary tests indicate that soil applications with chlordane and dieldrin are not highly effective against the cherry fruit fly.

# Comparison of Certain Organic Insecticides as Sprays or Baits against *Blattella germanica* (L.)[1]

SHAHZAMAN HUSAIN[2] and FRANK W. FISK, *Department of Zoology and Entomology, Ohio State University, Columbus*

The aim of these studies was to evaluate by laboratory screening techniques some of the synthetic organic insecticides which have been or could be used against the migratory grasshopper, *Schistocerca gregaria* Forsk., a major crop pest in Western Pakistan and elsewhere in the Middle East. Primary screening procedures may or may not employ the intended target species as one of the test insects and in this case it was impossible to do so. Consequently a commonly used test insect of the same order, namely the German cockroach, *Blattella germanica*, was selected. The insecticides used were either applied as sprays or offered as baits, representative of the two methods most widely used in grasshopper control in Pakistan.

APPARATUS AND PROCEDURE.—The German cockroaches were reared in a room far removed from the testing site in 5-liter capacity plastic jars covered with muslin and provided with ground dog chow as food, folded, corrugated paper strips for resting sites, and watering devices. The latter were water-filled plastic dishes with 3-inch dental wicks inserted through holes in the lids. By keeping a separate stock of mated females from which

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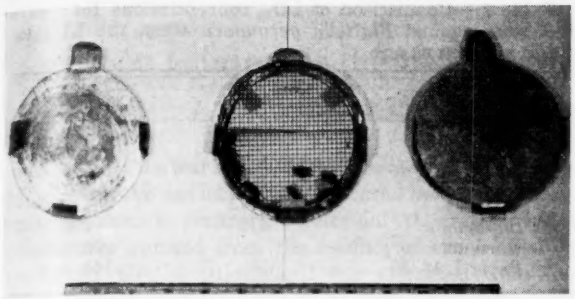

FIG. 1.—Petri-dish adapters and a petri dish with 8-mesh screen cover, ready for spraying.

the newly hatched progeny were removed twice weekly to set up a separate culture, the age of each culture was known. Six weeks after its initiation a culture consisted of young adults from which the females needed for testing could be removed.

The spray tests were conducted in a Jeffers-Ristich spray booth (as described by Husain 1954, and by Cole & Fisk 1955) using 9-cm. petri dishes hung vertically from the arms of a turnable operated within the booth. By taping filter paper discs to the bottoms of the petri dishes the test cockroaches were prevented from crawling under the papers, and at the same time were afforded a footing when the dishes were covered with 8-mesh screen covers and hung vertically for spraying (See Figure 1). The spray gun assembly operated on compressed air and included an air-driven stirrer useful in handling wettable powder suspensions. In operation 94 to 98 ml. of spray was applied from a distance of 3 feet towards four petri dishes revolving at 26 r.p.m. for a period of 1 minute. The insects were then anesthetized with $CO_2$, removed to separate clean petri dishes with filter paper, and placed at 25° C. for subsequent observation at 24, 48 and 72 hours. The importance of temperature control during this period has been emphasized by Guthrie (1950) and others.

In the bait tests ground dog chow was used as the carrier for the toxicants since it was obviously attractive to the test insect and could be made up into a workable wet bait by adding water at a rate corresponding to 2 gallons per 100 pounds of carrier. Dry bran baits have lately proved successful in the field (Parker 1952) but these were not used in our tests. Batches of poison bait were prepared by carefully mixing by hand a water concentrate of the appropriate insecticide with the carrier. The mixing was done under the chemical hood with the hands protected by rubber gloves. Two-ounce salve tins were then filled with the bait and covered securely with 8-mesh hardware cloth. This permitted the cockroaches to reach the bait by extending their mouthparts through the screen mesh. The test insects, all females, were starved 24 hours before being placed in 2-liter beakers with the bait tins. The bait remained available throughout the 72 hours of the experiment during which time the beakers were held at 25° C.

Table 1.—**Dosages required to kill 50 per cent and 95 per cent of *Blattella germanica* in spray and bait tests.**[a]

| | SPRAYS | | BAITS | |
|---|---|---|---|---|
| INSECTICIDE | $LD_{50}$ | $LD_{95}$ | $LD_{50}$ | $LD_{95}$ |
| Aldrin | .004 | .007 | .005 | .028[b] |
| Dieldrin | .007 | .012 | .014 | .075[b] |
| Endrin | .007 | .011[b] | .009 | .034[b] |
| Isodrin | .007 | .013[b] | .023 | .058 |
| Heptachlor | .016 | .033[b] | .013 | .044 |
| Diazinon | — | | .44 | — |
| Bayer L 13/59 | — | | .52 | — |

[a] Expressed as per cent of actual toxicant in the spray or bait. Mortalities at 72 hours.

[b] $LD_{95}$ values calculated from the data for 50% and 90% mortality by the method of Shepard (1934).

The insecticides evaluated were secured from the manufacturers in the following formulations: aldrin, dieldrin, endrin, isodrin and heptachlor were emulsifiable concentrates. Diazinon was wettable powder; while Bayer L 13/59 was a water-soluble technical powder.

RESULTS.—Results of the spray and bait tests are summarized in table 1 which shows the concentrations of spray and bait required to kill 50 per cent and 90 per cent of the test insects in 72 hours. All the spray tests were repeated at least once and, for the baits, the results of three different tests were combined for each level of concentration. Mortalities in the checks were usually zero; the maximum noted being 3.3 per cent. Mortalities at three or four dosages plus the checks were established for each insecticide. To determine the $LD_{50}$ for a given compound as spray or bait the 72-hour mortality data for one dosage were averaged and plotted as a point on logarithmic-probability paper. Then points for the other dosages were likewise plotted and the regression line fitted by eye (Finney 1947). From this line the $LD_{50}$ and, often the $LD_{95}$ also, could be easily read. In some experiments the highest mortality secured was less than 95 per cent. In these instances the $LD_{95}$ was not estimated by extrapolation, but calculated from Shepard's (1934) formula which may be used to derive the dosage for any mortality above 90 per cent if the $LD_{50}$ and $LD_{90}$ are known.

Figure 2 illustrates on a single graph the dosage-mortality lines plotted for aldrin as a spray and as a bait. The slopes of lines are notably different, indicating a greater variability with the bait experiments.

DISCUSSION.—When the toxicities of the several insecticides are compared it is found that aldrin was the most effective material both as spray and bait. Because of its superior effectiveness aldrin is taken as the standard material in table 2 in which the $LD_{50}$'s of the other compounds are compared to that of aldrin taken as unity.

Considering the spray data, dieldrin, endrin and isodrin appear to be about equal in toxicity while heptachlor is considerably lower, requiring a dose over four times that of aldrin. The relatively poor showing of heptachlor was checked by additional spray tests in which the culture of *Blattella germanica* used in these studies was compared to another "normal" culture of the same species. These later tests indicated a slightly greater susceptibility to heptachlor on the part of the "normal" culture, from which we infer that our culture had acquired a slight resistance, about two times the normal $LD_{50}$ to heptachlor.

Results of the bait tests as shown in table 2 indicate a different ranking of the experimental compounds. Contact or fumigant effects were minimized by the technique used. Therefore, the relative attractiveness of the bait as

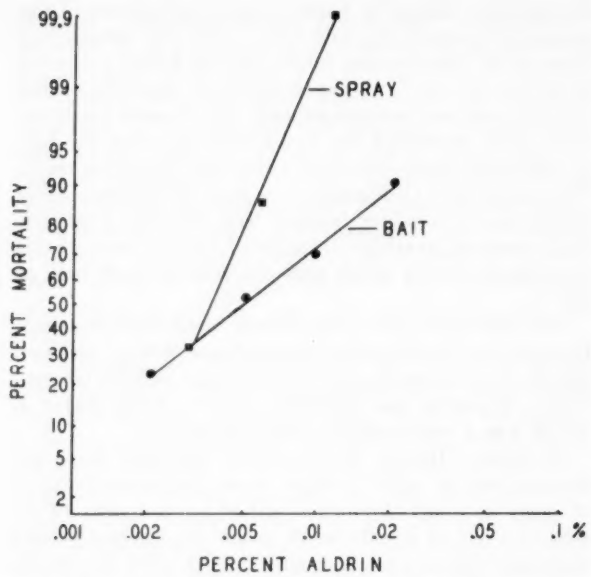


FIG. 2.—Per cent mortalities (Probit scale) of female *Blattella germanica* plotted as functions of dosage (log scale) of aldrin applied as a spray or offered as a bait.

a food was undoubtedly a primary factor determining the dosages taken up by the cockroaches. This would account for the appearance of differences in related chemicals such as dieldrin, endrin and isodrin, all of which were equally toxic when applied as sprays. Isodrin, with the lowest bait toxicity of the three, is assumed to be the least attractive. This reduced attractiveness could be due to an actual repellency of the poison itself or to certain solvents or other adjuvants present in the commercial concentrate. Heptachlor, on the other hand, was relatively more effective in the bait tests. Consequently it may be inferred that the heptachlor bait was relatively attractive and that if truly "normal" cockroaches had been used as the test insects it might have shown up better.

Another obvious factor in the bait tests is the mode of entry of the poison. Synthetic organic insecticides are generally most effective by contact or fumigant action and less toxic as stomach poisons (Beard 1949). The lower toxicity of the Diazinon may be due in part to this factor. However, both Diazinon and Bayer L 13/59 have been used as effective fly baits (Gahan *et al.* 1954), so that lower toxicity of those organic phosphates in our tests is more likely due to species specificity.

Neither of the screening techniques used in these studies evaluates the factor of residual toxicity. In actual spray programs for grasshopper control the longer residual action of dieldrin may more than compensate for its higher price as compared to aldrin.

SUMMARY.—Adult females of *Blattella germanica* (L.) were used to evaluate seven organic insecticides applied as water-dispersed sprays or offered as baits. The sprays were directed onto the test insects confined in petri dishes. In the bait tests, insecticides were diluted into a measured quantity of water and mixed into the carrier, ground dog food, keeping the amounts of water and carrier constant. The baits were offered in salve tins covered with 8-mesh hardware cloth through which the cockroaches could extend their mouthparts to feed.

Seventy-two hour mortality data were plotted on logarithmic-probability paper from which the $LD_{50}$ and $LD_{95}$ values are reported as per cent actual toxicant in the spray or bait.

Aldrin both as spray and bait appeared to be the most toxic insecticide of those tested. The ranking of the chemicals as to relative toxicity was different for each of the two methods of testing. For instance, heptachlor was more effective in a bait than when sprayed, while isodrin was much less effective in a bait. Possible reasons for isodrin's apparent lessened attractiveness as a bait are discussed.

**Table 2.—Comparison of $LD_{50}$ concentrations for sprays and baits against *Blattella germanica* when the $LD_{50}$ for aldrin is taken as one.**

| INSECTICIDE | SPRAYS | BAITS |
|---|---|---|
| Aldrin | 1.00 | 1.0 |
| Dieldrin | 1.75 | 2.8 |
| Endrin | 1.75 | 1.8 |
| Isodrin | 1.75 | 4.6 |
| Heptachlor | 4.2 | 2.6 |
| Diazinon | — | 88.0 |
| Bayer L 13/59 | — | 104.0 |

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# Control of the Pea Leaf Miner in Southern California[1]

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In May 1950 a leaf miner, *Liriomyza langei* Frick, sometimes called the pea leaf miner, appeared in large numbers on sugar beets in southern California. At first the small plants were stunted from the feeding of the adults, as practically all the chlorophyll was extracted from the upper surface of the leaves. Later the larvae made serpentine mines in the leaves and stems. A number of growers dusted their fields in May with 10 per cent toxaphene at 30 to 40 pounds per acre. Remarkable reductions were obtained, and the flies were held at a low level for about 3 weeks. Following a second application about June 10 the results were not satisfactory, the fly populations returning to the pre-application levels within 11 days, and it was decided to test several other insecticides against this leaf miner.

Frick (1951) reported this insect as a pest of peas, sugar beets, spinach, and celery in central California, and on asters in southern California. In southern California the mines in the petioles on spinach and romaine cause a premature wilting and dying of the lower leaves. Further damage is done by the adults of this or related species in puncturing the upper surface of the leaves with their ovipositors (Tilden 1950). On spinach, romaine, endive, and table beets these punctures cause white spots about $\frac{1}{16}$ inch in diameter, which are objectionable on the marketed product. More than 100 such spots have been counted on a single spinach leaf.

In 1951 the spinach leaf miner, *Pegomya hyoscyami* (Panz.), caused large blotch mines in the leaves of table beets in two experimental plots from July to September, but no damage was apparent in May and June. In 1953 similar damage was evident in table beets treated in June and July, but was not found on spinach treated in June. Therefore in 1953 observations were also made on the effect of the insecticides against this insect.

Methods.—In 1950 three fields of sugar beets, totaling 125 acres, which had previously been treated twice with 10 per cent toxaphene were divided into 30 large plots arranged at random across the fields. The plots were 143 feet (78 rows) wide and 1320 to 1980 feet long in two fields, and 140 to 160 (48 to 64) rows wide and 1320 feet long in the third field. Insecticides were applied once with a power duster between June 23 and July 1. In the third field a second application was made on July 11. Weekly sweepings were made in each plot to determine the number of flies surviving the treatments. Yield records were taken on beets from 700 to 900 feet of a single row in the middle of each plot harvested in October and November. Sugar analyses[2] were made from each plot.

Later tests were made on spinach, romaine, and table beets. Plots about 30 feet long and 4 to 6 beds wide (beds 3 feet apart) were arranged in randomized blocks with 4 or more replicates. Dusts were applied with rotary hand dusters, and sprays with a special high-pressure knapsack mist sprayer. Results on the pea leaf miner were checked by counting the mines in 10 leaves, and the adult feeding punctures on 10 half-leaves per plot, and results on the spinach leaf miner by counting the blotch mines on 40 leaves, or 20 feet of row per plot. One can count the blotch mines rapidly while walking slowly along the row.

Experiment on Sugar Beets in 1950.—On sugar beets fly populations in two of the fields never built up to the pre-application level, but in the third field this level was surpassed after 12 days. Beginning in August there was a general decline in all fields. All the materials gave fair control for 21 days, but none of the differences between treatments were significant. The plots treated with 20 per cent toxaphene yielded 0.93 to 2.92 tons of beets and 861 to 1371 more pounds of sugar per acre than plots treated with 2.5 per cent aldrin, 2.5 per cent dieldrin, 5 per cent chlordane, or 10 per cent toxaphene. However, these differences in yield were not significant.

Experiments in 1951.—*On spinach and romaine.*—One and 2 per cent parathion dusts were applied three times at weekly intervals at 15 pounds and twice at 2-week intervals at 30 pounds per acre. The infestation was low, but weekly treatments gave 100 per cent and biweekly treatments 81 and 95 per cent reduction of leaf mines. In reduction of leaf punctures, weekly applications gave fair control, and they were significantly better than applications made at 2-week intervals.

In a second experiment four applications of dust were made at weekly intervals at 15 pounds per acre on romaine, and three applications on spinach. In the reduction of leaf mines 1 per cent parathion gave excellent results and was significantly superior to 2 per cent lindane and to the check. Five per cent chlordane, 1 per cent TEPP, and 10 per cent toxaphene all gave fair results, but only chlordane was significantly better than the check. In reduction of leaf punctures all materials except lindane were significantly better than the check, but none gave good control.

In a third experiment several insecticides were applied at 30 pounds per acre three times at weekly intervals. The results are summarized in table 1. In the reduction of leaf mines parathion and EPN gave excellent results; toxaphene and Metacide good results; and heptachlor, dieldrin, aldrin, and isodrin poor to no control. In leaf punctures the results were from fair to poor, with no significant difference between treatments. Leaf burn was evident in the toxaphene plots after the second application. Any burning of the leaves of spinach reduces the market value of the product, so it must be avoided. Therefore, parathion was used on these plots for the third application. No burn was evident from the use of the other materials immediately after the third application, but 3 days later a severe smog occurred which accounted for most of the leaf burn shown in table 1. Significantly more burn was evident in the Metacide, parathion, and toxaphene-parathion plots than in any of the other treatments. Of the effective materials, EPN seemed the most promising.

[1] Accepted for publication March 25, 1955.

[2] The Holly Sugar Co., Santa Ana, Calif., made the sugar analyses and assisted in other ways.

**Table 1.—Control of the pea leaf miner on spinach and table beets in 1951 and 1953.**

| Insecticides | Mines | | Punctures | | Per Cent Plants Burned |
|---|---|---|---|---|---|
| | Per leaf | Reduction Per Cent | Per leaf | Reduction Per Cent | |
| | *Experiments in 1951* | | | | |
| On spinach: | | | | | |
| Parathion 2% | 0.03 | 98 | 50 | 33 | 16 |
| EPN 4% | .12 | 94 | 62 | 16 | 1 |
| Toxaphene 20% | .30 | 85 | 29 | 61 | 11 |
| Metacide 2% | .45 | 77 | 54 | 27 | 24 |
| Aldrin 5% | 2.12 | 0 | 73 | 1 | 4 |
| Dieldrin 2½% | 2.12 | 0 | 60 | 19 | 4 |
| Heptachlor 3% | 2.15 | 0 | 69 | 7 | 4 |
| Endrin 1% | 2.32 | 0 | 74 | 0 | 2 |
| Untreated check | 1.97 | — | 74 | — | 4 |
| L.S.D. (5% level) | 1.34 | — | —[a] | — | 7 |
| On table beets: | | | | | |
| Parathion 1% | .05 | 94 | 4.7 | 86 | 12 |
| Parathion 1%+DDT 5% | .13 | 85 | 20.5 | 39 | 10 |
| EPN 2% | .17 | 80 | 19.2 | 43 | 13 |
| EPN 2%+DDT 5% | .29 | 65 | 13.2 | 61 | 11 |
| DDT 5% | .52 | 38 | 13.6 | 60 | 9 |
| Untreated check | .83 | — | 33.7 | — | 7 |
| L.S.D. (5% level) | .31 | — | 2.0 | — | 3 |
| | *Experiment in 1953* | | | | |
| On spinach: | | | | | |
| Parathion 1% | .02 | 94 | 11 | 32 | 0 |
| EPN 2% | .05 | 81 | 14 | 16 | 0 |
| NPD 4% | .07 | 75 | 15 | 5 | 0 |
| Demeton 2% | .08 | 69 | 17 | 0 | 0 |
| Methyl parathion 2½% | .08 | 69 | 7 | 54 | 25 |
| Untreated check | .27 | — | 16 | — | — |
| L.S.D. (5% level) | .14 | — | —[a] | — | — |

[a] Differences not significant according to the *F* test.

*On table beets.*—Four experiments were conducted on table beets. In the first experiment two applications were made at 10-day intervals at 30 pounds per acre. Excellent control of leaf mines was obtained with parathion and poor control with heptachlor, toxaphene, aldrin, and dieldrin. Poor control of the leaf punctures was obtained with all materials.

In the second experiment four applications were made at weekly intervals at 20 pounds per acre. Excellent control of leaf mines was obtained with 2 per cent parathion; poor control with 4 per cent EPN and 2 per cent Metacide; and little or no control with 5 per cent aldrin, 5 per cent Perthane, 3 per cent heptachlor, 20 per cent toxaphene, and 2.5 per cent dieldrin. Poor control of leaf punctures was obtained with all materials.

In the third experiment ten applications of 1 per cent parathion and 2 per cent EPN were made at 10 pounds per acre at 3½-day intervals and five applications at 20 pounds per acre at 7-day intervals. Populations were low and no significant difference was apparent between treatments, but applications at 3½-day intervals were better than those at 7-day intervals. However, the percentage of plant burn was greater at 3½-day intervals. Both parathion and EPN gave excellent control of the spinach leaf miner, with no difference between the two schedules of application.

In the fourth experiment four applications were made at weekly intervals at 20 pounds per acre. In the reduction of leaf mines parathion gave excellent control; parathion plus DDT, and EPN gave good control; EPN plus DDT gave poor control; and DDT was significantly poorer than all others. The two parathion dusts were superior to the two EPN dusts. The addition of DDT to either parathion or EPN tended to reduce the effectiveness. In the reduction of leaf punctures parathion was superior to all other materials. DDT had less leaf burn than parathion or EPN. Parathion and EPN had more burn than the check. Parathion was again the most effective against the spinach leaf miner, but all materials gave excellent control of this insect except EPN, which was significantly less effective.

Experiments in 1953.—*On spinach.*—In the first of two experiments two applications were made a week apart at 15 pounds per acre. In the reduction of leaf mines parathion was best, and all materials were superior to the check, but with no significant difference between materials. Reduction of leaf punctures was fair with methyl parathion, and poor with all others. Methyl parathion severely burned the plants in the absence of smog conditions. There was no burn with the other materials.

In a second experiment three weekly applications were made at 15 pounds per acre for the dusts and at about 6 gallons per acre for the sprays. Excellent control (93 per cent) of leaf mines was obtained with 1 per cent parathion dust and 1.4 per cent EPN spray, fair control with 2 per cent EPN dust, and poor control with 2 per cent NPD and 2 per cent demeton dusts. All materials gave poor or no control of leaf punctures. No burn resulted from the applications in this field.

*On table beets.*—Five weekly applications were made at 15 pounds per acre for the dusts and at 5 gallons per acre for the sprays. As shown in table 2, the parathion dust

**Table 2—Control of leaf miners on table beets in experiment 1, 1953.**

| Insecticide | Pea Leaf Miner | | | | Spinach Leaf Miner | | Plantburn Rating[b] |
|---|---|---|---|---|---|---|---|
| | Mines | | Punctures | | Mines | | |
| | Per Leaf | Per Cent Reduction | Per Leaf | Per Cent Reduction | Per 20 Feet of Row | Per Cent Reduction | |
| Parathion 1% dust | 0.10 | 94 | 6 | 43 | 2.0 | 89 | 2.0 |
| EPN 1.4% spray | .09 | 94 | 6 | 43 | 1.2 | 94 | 1.7 |
| EPN 2% dust | .51 | 67 | 7 | 30 | 2.8 | 86 | 1.2 |
| NPD 4% dust | .79 | 49 | 12 | 0 | 0.2 | 99 | 1.2 |
| Demeton 2% dust | .81 | 48 | 6 | 37 | 1.7 | 91 | .5 |
| Untreated check | 1.54 | — | 10 | — | 18.5 | — | .7 |
| L.S.D. (5% level) | .41 | — | [a] | — | 4.2 | — | .7 |

[a] Not significant according to the *F* test.
[b] 0, no burn; 1, 1 per cent; 2, 5 per cent; and 3, 10 per cent of the plants burned.

and the EPN spray gave excellent control of leaf mines and were significantly better than the other materials. In leaf punctures there was no significant difference between materials. The most plant burn occurred in the parathion-dust and EPN-spray plots, which had about 5 per cent of the plants burned. However, the burn was slight and in most cases could be trimmed off. NPD dust, EPN spray, and dusts of demeton, parathion, and EPN gave excellent or very good control of the spinach leaf miner.

SUMMARY.—In 1950 the pea leaf miner, *Liriomyza langei* Frick, appeared in injurious numbers on sugar beets in southern California. Field tests with 10 and 20 per cent toxaphene, 2.5 per cent aldrin, 2.5 per cent dieldrin, and 5 per cent chlordane indicated that they were only fairly effective for the control of the adult flies. In experiments on spinach, romaine, and table beets excellent results in the reduction of serpentine leaf mines were obtained with 1 or 2 per cent parathion applied weekly at 15 pounds per acre, and excellent to good results when applied at 2-week intervals at 30 pounds per acre. EPN emulsion sprays gave excellent results in two tests. Dusts of EPN, and Metacide usually gave good results. Dusts of heptachlor, dieldrin, aldrin, isodrin, chlordane, TEPP, toxaphene, lindane, DDT, NPD, demeton, and methyl parathion gave only fair to poor results. None of the materials gave satisfactory reduction in leaf punctures of the adult flies on the upper surface of the leaves.

Twenty per cent toxaphene and 2.5 per cent methyl parathion dusts burned the leaves of spinach severely in the absence of smog conditions. One per cent parathion and 2 per cent EPN dusts in the presence of smog intensified the burn on the leaves, and more burn was obtained when they were applied at 3½-day than at 7-day intervals.

Beets and spinach were damaged also by the spinach leaf miner, *Pegomya hyoscyami* (Panz.). Excellent to very good control was obtained with dusts of 1 per cent parathion, 2 per cent EPN, 1 per cent parathion plus 5 per cent DDT, 2 per cent EPN plus 5 per cent DTT, 5 per cent DDT, 4 per cent NPD, 2 per cent demeton, and with a 1.4 per cent EPN spray.

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# Control of the Strawberry Aphid in Southern California[1]

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Experiments for the control of the strawberry aphid, *Capitophorus fragaefolii* (Ckll.), were conducted in southern California from 1949 through 1953. This insect is a serious pest here from February through April, but of little importance the remainder of the year. Growers have claimed that nicotine dust is ineffective during the cool weather that prevails at this time of the year, and that TEPP sprays burn the foliage under some conditions.

The experiments were conducted in commercial fields of Klondike strawberries near San Juan Capistrano in 1949 and 1950, and of Lassen strawberries near Stanton from 1951 to 1953. The strawberries were planted in beds 3 to 3½ feet apart. The plots were three to six beds wide and 30 to 60 feet long and arranged in four or more randomized blocks. Dusts were applied with rotary hand dusters equipped with two nozzels mounted about 8 inches apart on a Y tube so that both rows of plants on the bed could be treated at once. Concentrated sprays prepared from emulsifiable concentrates were applied with a high-pressure knapsack mist sprayer at 5 to 10 gallons per acre. Counts of live aphids per leaflet were made on five or more leaflets per plot. Usually only one application was made, but additional applications were sometimes made when the test material was not effective or when mites also needed to be controlled.

The sprays were prepared from concentrates containing the following insecticides at the indicated pounds per gallon: lindane 1.6, TEPP 4, parathion 2, schradan 4, Isolan 2, Pyrolan 2, sulfotepp 8.96, Chlorobenzilate 2, R-242 2, DMC 2, Metacide 4, NPD 7.65, Ovotran 2, endrin 1.5, demeton 3, nicotine 4. These materials were diluted with water on a weight basis to give the percentages shown in the tables.

1949 EXPERIMENTS.—In experiment 1 the application was made on February 15. All materials gave good control after 2 days, but by March 1 there was a buildup of the population in all but the lindane plots. All treatments were significantly better than the check, but there were no significant differences between treatments (Table 1). In experiment 2 stronger dusts of parathion were used and were compared with sprays of TEPP and parathion. The application was made on February 18, and 10 counts on five leaflets per plot were made at about weekly intervals until May 11. The parathion dusts gave the best results and were statistically superior to the TEPP sprays, but the dusts were not superior to the parathion spray.

As a result of these experiments, 1 and 2 per cent parathion dusts were used generally for the control of the strawberry aphid in southern California in 1949 and 1950. One grower estimated that one application of 1 per cent parathion at 30 pounds per acre would give him excellent control for the season at a cost of $5.36 per acre for

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**Table 1.—Strawberry aphids surviving one application of insecticides to Klondike strawberry plants at San Juan Capistrano, Calif., 1949.**

| Insecticide | Rate per Acre (Pounds of Dust or Gallons of Spray) | Surviving Aphids per Leaflet | |
|---|---|---|---|
| | | Number | Per Cent Reduction |
| *Experiment 1—1949* | | | |
| Lindane 1% spray | 6 | 0.2 | 97 |
| TEPP 0.8% spray | 9 | 1.4 | 83 |
| Parathion 0.5% dust | 30 | 1.4 | 83 |
| TEPP 1.9% spray | 9 | 1.6 | 82 |
| Parathion 0.25% dust | 35 | 2.2 | 74 |
| Untreated check | — | 8.8 | — |
| L.S.D. (5% level) | — | 5.2 | — |
| *Experiment 2—1949* | | | |
| Parathion 2% dust | 29 | .6 | 93 |
| 1% dust | 29 | 1.3 | 89 |
| 0.8% spray | 6 | 2.0 | 76 |
| TEPP 1.6% spray | 3 | 3.4 | 60 |
| | 6 | 4.9 | 43 |
| Untreated check | — | 8.7 | — |
| L.S.D. (5% level) | — | 1.8 | — |

labor and materials, whereas with 4 per cent nicotine dust the cost would be $17 per acre for two applications with only fair control. Residue analyses on berries 1 and 4 days after dusting with 0.5 and 1 per cent parathion at 30 pounds per acre showed less than 1 p.p.m.[2]

1950 Experiment.—One per cent parathion dust was compared with other phosphorus dusts and with a schradan spray. Most of the materials were applied on February 2. Counts were made on February 3, 9, and 23, and on March 8 and 23. Parathion and TEPP gave excellent control, and EPN and TIPP (tetraisopropyl pyrophosphate) gave poor control, as shown in table 2. A second application of TIPP was made on February 16, at which time the schradan applications were also made. The results were very good with the schradan spray, but were poor with the schradan and TIPP dusts. Parathion and TEPP continued to hold the aphids at a fairly low level.

1951 Experiment.—This experiment was conducted for the joint control of the two-spotted spider mite, *Tetranychus telarius* (L.), and the strawberry aphid.

**Table 2.—Tests of phosphorus compounds against the strawberry aphid. 1950.**

| Insecticide | Rate per Acre (Pounds of Dust or Gallons of Spray) | Number of Applications | Surviving Aphids per Leaflet | |
|---|---|---|---|---|
| | | | Number | Per Cent Reduction |
| Schradan 1.2% spray | 5 | 1 | 0.5 | 86 |
| Parathion 1% dust | 30 | 1 | .8 | 76 |
| TEPP 1% dust | 28 | 2 | 1.2 | 65 |
| Schradan 1% dust | 31 | 1 | 1.9 | 46 |
| TIPP 1% dust | 62 | 2 | 2.9 | 16 |
| EPN 1% dust | 28 | 1 | 4.2 | 0 |
| Untreated check | — | — | 3.5 | 0 |
| L.S.D. (5% level) | — | — | 1.4 | — |

**Table 3.—Control of strawberry aphids with various insecticides applied to Lassen strawberry plants at Stanton, Calif. 1951–1953.**

| Insecticide | Number of Applications | Rate per Acre (Pounds of Dust or Gallons of Spray) | Surviving Aphids per Leaflet | |
|---|---|---|---|---|
| | | | Number | Per Cent Reduction |
| *Experiment—1951* | | | | |
| Schradan 2.4% spray | 1 | 6 | 0 | 99 |
| Parathion 2% dust | 2 | 75 | 0.1 | 99 |
| Malathion 5% dust | 2 | 68 | .1 | 98 |
| Demeton 1.8% spray | 1 | 7 | .2 | 97 |
| Ovotran 10% dust | 2 | 68 | 2.5 | 45 |
| Sulphenone 10% dust | 2 | 66 | 2.9 | 36 |
| Bis(*p*-chlorophenyl)ethynyl carbinol 5% dust | 1 | 35 | 4.0 | 12 |
| Aramite 3% dust | 2 | 68 | 4.5 | 0 |
| L.S.D. (5% level) | — | — | 2.9 | — |
| *Experiment 1—1952* | | | | |
| Isolan 1.2% spray | 2 | 15 | .2 | 95 |
| Metacide 1% dust | 2 | 68 | .3 | 93 |
| Pyrolan 1.2% spray | 2 | 17 | .4 | 91 |
| Endrin 1% dust | 2 | 69 | .5 | 86 |
| TEPP 1% dust | 2 | 76 | 1.5 | 64 |
| Pyrolan 2% dust | 2 | 78 | 1.5 | 64 |
| Nicotine 4% dust | 2 | 67 | 1.9 | 55 |
| Isodrin 1% dust | 2 | 66 | 2.1 | 51 |
| Untreated check | — | — | 4.3 | — |
| L.S.D. (5% level) | — | — | 1.4 | — |
| *Experiment 2—1952* | | | | |
| Sulfotepp 3.6% spray | 1 | 25 | .1 | 97 |
| Lime-sulfur 1% plus nicotine 0.1% spray | 1 | 404 | .8 | 74 |
| Nicotine 0.1% spray | 1 | 404 | 1.5 | 54 |
| Oil[a] 1% plus nicotine 0.1% spray | 1 | 404 | 1.8 | 45 |
| Lime-sulfur 1% spray | 1 | 404 | 3.5 | 0 |
| Oil[a] 1% spray | 1 | 606 | 3.9 | 0 |
| Chlorobenzilate 0.03% spray | 1 | 425 | 5.8 | 0 |
| DN-289 0.03% spray | 1 | 445 | 8.7 | 0 |
| Untreated check | — | — | 3.3 | — |
| L.S.D. (5% level) | — | — | 2.8 | — |
| *Experiment 3—1952* | | | | |
| Metacide 1.2% spray | 1 | 8 | .5 | 100 |
| Demeton 1.8% spray | 1 | 5 | .6 | 98 |
| TEPP 0.5% plus R-242 0.6% spray | 1 | 8 | 2.0 | 92 |
| Schradan 2.4% spray | 1 | 5 | 2.0 | 92 |
| TEPP 1% dust | 1 | 39 | 8.3 | 69 |
| Chlorobenzilate 0.8% spray | 1 | 8 | 12.0 | 55 |
| Ovotran 10% dust | 1 | 38 | 14.9 | 44 |
| Chlorobenzilate 2% dust | 1 | 37 | 20.2 | 24 |
| Sulfur 25% dust | 1 | 32 | 26.5 | 0 |
| Aramite 3% dust | 1 | 37 | 28.0 | 0 |
| DMC 0.6% spray | 1 | 12 | 36.2 | 0 |
| DN-289 1.1% dust | 1 | 34 | 39.7 | 0 |
| L.S.D. (5% level) | — | — | 15.1 | 0 |
| *Experiment 1—1953* | | | | |
| Demeton 2% dust | 3 | 96 | 0 | 100 |
| TEPP 1% dust | 7 | 287 | 0 | 100 |
| Metacide 1.6% spray | 3 | 25 | 0 | 100 |
| NPD 4.6% spray 4% dust | 3 5 | 25 199 | 0 0 | 100 100 |
| TEPP 0.66% plus Sulphenone 0.8% spray | 5 | 40 | 0 | 100 |
| Demeton 0.8% spray | 2 | 9 | .3 | 96 |
| DMC 0.6% spray | 6 | 52 | 2.6 | 74 |
| Ovotran 10% dust | 3 | 120 | 4.0 | 61 |
| 0.6% spray | 5 | 43 | 5.2 | 49 |
| Aramite 3% dust | 2 | 78 | 5.5 | 46 |
| Bis(*p*-chlorophenyl)ethynyl carbinol 10% dust | 2 | 98 | 10.3 | 0 |
| L.S.D. (5% level) | — | — | 2.0 | — |
| *Experiment 2—1953* | | | | |
| Isolan 1.2% spray | 1 | 5 | .1 | 98 |
| Endrin 0.9% spray | 1 | 6 | .3 | 96 |
| NPD 4% dust | 1 | 33 | .7 | 89 |
| Isodrin 2% dust | 3 | 107 | 1.6 | 77 |
| Pyrolan 1.2% spray | 3 | 17 | 1.8 | 75 |
| TEPP 1% dust | 4 | 141 | 2.4 | 66 |
| Nicotine 4% dust | 5 | 148 | 4.4 | 38 |
| Untreated check | — | — | 7.1 | — |
| L.S.D. (5% level) | — | — | 1.0 | — |

[a] Light-medium spray oil, 52–61% distilled at 636° F., unsulfonated residue 92%.

[2] Analyses made by the California Department of Agriculture, Bureau of Chemistry, Sacramento, Calif.

Both dusts and sprays were applied on April 6, May 9, June 14, and July 25, and the dusts also on April 24. Aphid counts were made on April 12 and 30, when the populations were heaviest. As shown in table 3, excellent results were obtained with malathion, parathion, schradan, and demeton (all phosphorus compounds), and poor results with Ovotran, Aramite, bis(*p*-chlorophenyl)-ethynyl carbinol, and R-242. However, by September the parathion and malathion plots were severely infested with the cyclamen mite, *Tarsonemus pallidus* Banks.

Persing (1950) and Huffaker & Spitzer (1951) found in 1950 that the use of parathion on strawberries caused a buildup of the cyclamen mite. We obtained similar results in 1951. This buildup was not so noticeable when only one application of 1 per cent parathion was made in the early spring for aphid control, but where repeated applications of 1 and 2 per cent parathion were made for control of the two-spotted mite the cyclamen mite built up to damaging numbers. Therefore, no further tests were made of parathion on strawberries.

1952 EXPERIMENTS.—Experiment 1 was a test of several of the new insecticides. Two applications were made, on March 3 and April 9, and four counts, on March 6 and 28, April 15, and May 1. Metacide and endrin dusts and Isolan and Pyrolan sprays gave excellent to very good control in this order, and they were significantly better than dusts of nicotine or isodrin, as shown in table 3.

Experiment 2 was a test of several sprays applied mainly for control of the cyclamen mite. Sulfotepp was applied by hand as a high-pressure mist spray, and all other materials with a spray gun operated from a power sprayer at 350 pounds' pressure. Results shown in table 3 are the average of two counts, made on February 27 and 28. Excellent control of the strawberry aphid was obtained only with sulfotepp. DN-289 (triethanolamine salt of dinitro-*sec*-butylphenol, 36 per cent), and lime-sulfur burned the plants, and sulfotepp caused slight but significant burn.

Experiment 3 in 1952 was a test of materials applied for the control of the two-spotted spider mite. A count of the aphids on April 14, 11 days after the first application, showed that excellent control had been obtained with Metacide, demeton, TEPP plus R-242, and schradan sprays; fair control with TEPP dust, and poor control with the remaining materials.

1953 EXPERIMENTS.—Experiment 1 in 1953 was also chiefly for the control of the two-spotted spider mite. All materials were applied on February 5, and additional applications were made as necessary to hold the population to five mites per leaflet. Table 3 shows the number of applications needed up to April 7, and the average number of aphids per leaflet on March 30 and April 7. All materials gave excellent aphid control except DMC, Ovotran, Aramite, and bis(*p*-chlorophenyl)ethynyl carbinol. The last material was used as a check in calculating per cent reductions.

In experiment 3 in 1952 and experiment 1 in 1953 (Table 3), the plots treated prior to April 8 with ineffective materials (Aramite, Ovotran, DMC, Chlorobenzilate, sulfur, and DN-289) were dusted with 4 per cent nicotine at 50 pounds per acre twice, a week apart, following the last date of counting. Satisfactory control was obtained for the remainder of the season.

Experiment 2 in 1953 was made primarily for aphid control, and the first application of each material was made on March 20. Counts were made weekly for 8 weeks, and additional applications were made as needed. Excellent control was obtained with a single application of Isolan and endrin, and very good control with one application of NPD. Each of these treatments was significantly better than three or more applications of most of the other materials tested.

SUMMARY.—The strawberry aphid, *Capitophorus fragaefolii* (Ckll.), is a serious pest of strawberries in southern California from February through April. Experiments conducted from 1949 through 1953 showed excellent control with dusts of parathion, malathion, Metacide, endrin, demeton, and NPD; and with sprays of lindane, schradan, demeton, Isolan, Pyrolan, sulfotepp, Metacide, TEPP plus R-242, NPD, and endrin. Fair to good control was obtained with dusts of TEPP, nicotine, isodrin, and with sprays of parathion, and lime-sulfur plus nicotine. Poor to no control was obtained with dusts of Ovotran, Aramite, bis(*p*-chlorophenyl)ethynyl carbinol, sulfur, DN-289, Chlorobenzilate, R-242, TIPP, EPN, and schradan; and sprays of TEPP, oil plus nicotine, oil, lime-sulfur, Chlorobenzilate, DN-289, and DMC.

Parathion, malathion, and Metacide cannot be used on strawberries, because the cyclamen mite tends to build up after their use. Endrin, demeton, lindane, schradan, Isolan, and Pyrolan may present a residue hazard, or cannot be used until more is known of their residual properties.

DN-289 dust and spray severely burned the plants, and lime-sulfur and sulfotepp caused noticeable burn when applied in April but not in February.

A dust of 4 per cent nicotine is effective if two applications are made a week apart at about 50 pounds per acre, beginning when there are about five aphids per leaflet.

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# Validity of the Insecticidal Check Method as a Measure of the Effectiveness of Natural Enemies of Diaspine Scale Insects[1]

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Strangely enough, neither the fact nor the degree of biological control has been proved formally in many cases which are widely accepted as highly effective. In recognition of this situation, Smith & DeBach (1942) and DeBach *et al.* (1949, 1951) reviewed the problem and suggested various approaches toward more accurate evaluation of the effectiveness of entomophagous species.

It was pointed out by these writers that correlation between changes in host and natural enemy populations —the empirical method of evaluation of biological control—has inherent weaknesses so far as definite proof of the effectiveness of the natural enemies is concerned. Experimental methods designed to measure host population trends in the presence and absence, or near absence, of natural enemies were shown to offer means of definite proof of the effectiveness of the natural enemies. For one of these, the "insecticidal check method," DeBach (1946) suggested use of an insecticide relatively nontoxic to the host to eliminate natural enemies from certain plots and then comparison of host population trends in these and adjacent untreated plots to measure the total effectiveness of the natural enemies.

Various possible limitations of this insecticidal check method were recognized at the time of its development, and DeBach (1946) stated: "Residues nontoxic to the host but toxic to its natural enemies may, entirely aside from the elimination of the natural enemies, make conditions more favorable for host population increase." Fleschner (1952) showed such an effect with *Metatetranychus* (*Paratetranychus*) *citri* (McG.), in that egg populations became heavier and remained so for appreciable periods on foliage treated with DDT and zinc sprays, as compared with populations on untreated foliage in the absence of natural enemies. Subsequent work (Hueck 1953) has shown that such an effect also occurs with *Metatetranychus ulmi* Koch on leaves bearing DDT residues. This mite lays more eggs on foliage bearing DDT residues than on untreated foliage.

These findings and Hueck's (1953) discussion raise a question as to the general validity of conclusions based on the insecticidal check method, because other mites and insects may be similarly affected. These results also raise the question as to whether the numerous instances of pest population upsets recorded in the literature are caused by reduction of natural enemy populations, as most authors believe, or by some physiological effect of the insecticide which directly or indirectly tends to promote increase of the host population, or by a combination of the two. This paper presents evidence showing that DDT does cause population increases of the California red scale, *Aonidiella aurantii* (Mask.), and the yellow scale, *Aonidiella citrina* (Coq.), on treated citrus trees in the field, *but only as a result of selective elimination of natural enemies.*

CALIFORNIA RED SCALE STUDIES.—A brief history of the present biological control project on the California red scale may furnish background information pertinent to this discussion. Detailed ecological studies of the California red scale and its natural enemies on citrus in the field were begun in 1948. The first objective was to evaluate the total effectiveness of entomophagous species considered as a group, and the relative effectiveness of each species considered separately. When this had been determined it was hoped that the effectiveness of one or more entomophagous species could be enhanced by insectary culture and field colonization or by some other method of manipulation which might become apparent as more ecological information was acquired.

In order to evaluate the effectiveness of the natural enemies, experimental groves had to be obtained in which no insecticides were used for any pests. This was a difficult undertaking in southern California, where insecticidal pest control on citrus is widely practiced. However, through the cooperation of the County Agricultural Commissioners and the California Agricultural Extension Service, a few groves were found in which insecticides had not been used for several years, and hence in which populations of the natural enemies had not been "upset" by the use of insecticides. Surprisingly, the California red scale infestation in most of these groves was quite low even though some had not been treated for as many as 10 years. Obviously, a determination of the factors responsible for this condition was extremely important. Various methods of analysis for the mortality factors responsible were consequently undertaken.

Three methods of experimental mensuration—the insecticidal check method, the sleeve-cage check method, and the biological check method—were being tested within different groves by the end of 1948 (DeBach *et al.* 1953). Each of these methods eliminated or inhibited the development of natural enemies, each complemented the other, and each resulted in similarly striking increases of scale populations. By a process of elimination it was determined that the only factors that could have caused appreciable mortality of the California red scale in these groves were natural enemies.

Use of the insecticidal check method and the sleeve-cage check method served to rule out climate, disease, and varietal resistance as causes of significant mortality. The biological check method, which utilized ants to inhibit and eliminate natural enemies, likewise ruled out all known causes of mortality other than natural enemies, and in addition precluded the possibility that some benefit might have derived to the scales from modification of the environment due to the use of insecticides or sleeve cages.

These results are all documented in the citations previously listed and would seem to constitute incontrovertible experimental proof that the California red scale was

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[3] Mr. E. J. Dietrick, Principal Laboratory Technician, was responsible for the acquisition of a large part of the field data.

effectively controlled by natural enemies in the several plots studied. Where satisfactory biological control of the California red scale existed at low population densities, it was found that *Aphytis chrysomphali* Mercet was the dominant control factor, since it was the only natural enemy present causing appreciable mortality of the scale. Later, after importation from China and Formosa, *Aphytis* "A"[4] was also found to be a controlling factor.

By 1949 it became evident that the DDT insecticidal check method was the easiest and most satisfactory method of measuring the effectiveness of natural enemies of the California red scale, particularly if no other effects of DDT than elimination of natural enemies were involved, or if such effects could be evaluated.

Experiments were accordingly conducted to determine whether or not other effects of DDT existed. A lemon grove near Claremont (Stover's) was chosen as ideal for this purpose, inasmuch as natural enemies of the California red scale were so scarce in this grove as to be virtually nonexistent. Hence, other factors which might affect scale population changes could readily be measured. The scale population in the grove was well distributed and very light but increasing.

Two series of experiments were conducted: in one, tests with and without DDT on the foliage were run in sleeve cages; in the other, tests were run on entire trees in the open, some trees being treated with DDT, some being treated with other insecticides, and some remaining untreated.

*Sleeve-Cage Tests.*—The sleeve-cage tests were conducted for approximately 7 months (from February 8 to September 28), during that part of the year most favorable to scale increase. During this period a heavy buildup of scales occurred. The tests were terminated when parasites first entered the plots.

In February, March, and May, because of the generally low natural scale infestations available within the sleeve cages, each test branch was artificially infested with equal numbers of red scale crawlers from the insectary. During the test period 2 field generations of scale developed. DDT spray was applied to the treated branches each month at a very light application of a low-dosage formulation of 2 pounds of actual DDT (5 pounds of wettable powder, 40 per cent) per 100 gallons of water. This was standard procedure in all DDT check-tree tests in all groves. Monthly spray applications had been determined by previous tests to be the most desirable interval for keeping parasites at a minimum and yet not affecting scales appreciably. Longer intervals permitted too much parasite activity to develop, shorter intervals resulted in relatively high insecticide mortality to scale crawlers.

Upon termination of the tests the sleeve cages were removed and the branches which had been enclosed were cut from the trees to facilitate rating the scale population. Seven entire branches were involved, 3 treated with DDT and 4 untreated. Each was rated relative to the other as to scale population density and as to degree of damage to leaves and twigs by the scales. Two observers were in complete agreement with regard to these ratings, which are presented in table 1.

It is evident from the data that, on the average, the greatest scale increase and damage occurred on the untreated branches, or, conversely, that DDT residue on the branches certainly caused no increase and probably caused a decrease in scale populations as compared with untreated checks. However, without exception, in the many cases where DDT has been applied to California red scale-infested citrus trees *also having parasites well established*, the scale populations on the treated foliage have increased strikingly, as compared with populations on the untreated foliage. That such did not occur in the tests just described would seem to indicate clearly that DDT has no beneficial effect on California red scale populations other than indirectly through the inhibition of natural enemies.

**Table 1.—Effect of light applications of a low-dosage DDT formulation on relative population increase of California red scale and degree of damage from scales on lemon branches sprayed monthly over a 7 months' period in sleeve-cage tests in the absence of effective natural enemies. Stover grove, 1949.**

| Treatment | Branch | Rating (1 = Lightest; 7 = Heaviest) | |
|---|---|---|---|
| | | Final Scale Population Density | Degree of Leaf and Twig Damage |
| DDT | 1 | 2 | 4 |
| | 2 | 4 | 1 |
| | 3 | 2 | 1 |
| Average | | 2.7 | 2.0 |
| Untreated | 4 | 7 | 7 |
| | 5 | 1 | 3 |
| | 6 | 5 | 5 |
| | 7 | 6 | 6 |
| Average | | 4.8 | 5.3 |

*Entire Tree Tests.*—Additional tests in the Stover grove during 1949, in which entire trees were used in the open, substantiate the foregoing conclusion. The purpose of these tests was threefold: 1) to determine whether there was an effect associated with the use of DDT or certain other insecticides, which, acting through the physiology of the tree, might result in red scale population increase; 2) to determine whether there was any physical effect of insecticidal residues on red scale population increases; and 3) to compare the effects of the use of DDT with those of BHC, methoxychlor, toxaphene, and DDD. Toward this end an experimental block was established in the same lemon grove (Stover's), in which natural enemies of red scale were virtually nonexistent. This block consisted of 3 randomly situated replicates for each of the 5 insecticides and the untreated check.

As previously mentioned, the red scale infestation in this grove was light and rather uniformly distributed among the trees at the start of the experiment. The three replicates for each treatment were so grouped on the basis of initial scale counts that each contained trees representing a similar range of initial populations. Sprays of a spray-dust type were first applied February 21, 1949, and applications were repeated thereafter at approximately monthly intervals.

[4] Since described as *Aphytis lingnanensis* Compere.

**Table 2.—Effect of light applications of low-dosage formulations of various insecticides on California red scale population increase on lemon trees sprayed monthly over a 7 months' period in the absence of effective natural enemies. Stover grove, 1949.**

| Treatment | Scale Population Density per Tree | |
|---|---|---|
| | Initial Count, February 21 | Final Count, September 28 |
| DDT | 22 | 39 |
| DDD | 9 | 41 |
| Methoxychlor | 9 | 23 |
| Toxaphene | 8 | 63 |
| BHC | 19 | 38 |
| Untreated | 7 | 68 |

The spray dosages used were purposely light in order to avoid mortality to the scales, and only about ½ gallon of the mixture was applied per tree. The DDT check-tree program (previously described) was the same in all parasite test groves, and had in all previous cases produced striking increases in red scale populations as compared with untreated trees having natural enemies present. Parasites (*Aphytis*) were first found in small numbers in these plots on September 28, 1949, at which time the studies were necessarily terminated and final counts were made (Table 2).

In this case, again, where natural enemies were not a factor, no differential increase of scales occurred on the DDT-treated trees or on any of the trees treated with the other insecticides. In fact, in every case the insecticidal residue seemed to produce a slight to marked inhibition of red scale population increase. This was particularly true with the DDT-treated trees, which showed the highest initial infestation and one of the lowest final infestations. Again we must emphasize that such a result had never been obtained before these tests, and has not been obtained since, in the presence of effective natural enemy populations. For instance, by the following spring (1950) the parasite *Aphytis* "A" had been colonized in this same Claremont grove (Stover's) in large numbers and was vigorously at work attacking red scales. A DDT check test was started in May, 1950, when the first DDT spray was applied, and initial counts were made on the DDT-treated tree and on an untreated tree. Treatments and counts were repeated at monthly intervals. Within 4 months, as shown in table 3, marked differences in scale populations were apparent between the untreated tree (parasites abundant) and the DDT check tree (parasites reduced by DDT). By the end of the year the scale infestation was extremely heavy and damaging on the DDT tree, whereas it was still low on the untreated tree. This is in striking contrast to the results of the year before when, in the absence of effective parasites, DDT caused no differential increase in scale population.

Similar tests in other "biological control" groves, have in nearly every case studied resulted in similarly striking relative increases in scale populations. This has occurred in spite of the fact that DDT, as used, caused some mortality to red scale (see Tables 1 and 2). The only possible conclusion seems to be that DDT residues certainly had no tendency to increase California red scale populations as a result of altering the physiology of the tree or of the scale, or of modifying the substratum physically. Such DDT residues, in fact, appear to have a retarding effect on red scale population increase. Thus, it seems apparent that the striking increases in California red scale populations which occur on DDT check trees in biological control plots can only be attributed to elimination or inhibition of natural enemy populations.

Various field observations further confirm the experimental results reported above. For instance, early in 1949 a plot well infested with California red scale was established in an untreated citrus grove (Martin's, San Bernardino) for the colonization of large numbers of red scale parasites (*Aphytis*). A DDT check tree in this plot was treated first on June 15 and thereafter at monthly intervals with the standard formulation and procedure already described. By September this tree was so heavily infested with red scale, in comparison with other trees in the block, on which *Aphytis* had been successfully working, that it was difficult not to believe that some factor other than the elimination of parasites by DDT might be responsible for red scale increase on the tree. However, examination of trees in the far end of the grove, which had not received parasite colonizations, showed that these trees were as heavily infested as was the DDT check tree in the parasite plot, thus indicating that the increase of scales on the DDT check tree was solely a result of the elimination of parasites by DDT. Similar observations have been made in other groves.

Other evidence has been derived from comparison of red scale population increases on DDT trees with nearby biological check trees on which ants were exceptionally abundant. Ants affect diaspine scales only indirectly through the elimination or inhibition of natural enemies. There is no other known or postulated effect of ants on diaspine scales which might result in population increases. In several cases the elimination of natural enemies by ants was so efficient that scale populations increased about as rapidly, and to the same approximate magnitude, as on the DDT check trees, thus again indicating that the only effect of DDT was to inhibit natural enemy populations.

Neither the DDT check nor the biological check method eliminates natural enemies from the trees completely. Natural enemies also continually migrate from surrounding untreated trees and may feed or oviposit before being killed by DDT. Furthermore, DDT, even at the light dosages used, tends to retard the increase of red

**Table 3.—Effect of light applications of a low-dosage DDT formulation on California red scale population increase on lemon trees over a 5 months' period in the presence of effective natural enemies.[a] Stover grove, 1950.**

| Month of Spray Treatment and Scale Count | Scale Population Density per Tree | |
|---|---|---|
| | Untreated | DDT-Sprayed |
| May | 3 | 10 |
| June | 6 | 5 |
| July | — | — |
| August | 4 | 79 |
| September | 3 | 43 |

[a] Principally *Aphytis* "A."

scale populations somewhat. Hence the DDT check method actually presents a conservative measure of the effectiveness of natural enemies of the California red scale rather than an exaggerated one.

Yellow Scale Studies.—The DDT check method used to measure the effectiveness of natural enemies of the yellow scale was identical with that used with the California red scale. A very light application of a low-dosage DDT formulation (5 pounds of wettable powder, 40 per cent) per 100 gallons of water was made at monthly intervals.

Tests were carried out in one grove where parasites and/or predators were virtually nonexistent, and in several groves where parasites (dominantly *Comperiella bifasciata* Howard) were abundant. A comparison between these two situations will show whether or not DDT, as used, had any tendency to cause yellow scale population to increase, and whether DDT sufficiently retarded *Comperiella* to constitute a good method of evaluation.

In the first grove (Peterson's at Strathmore), where parasites were no factor (actually, an average of 0.5 per cent parasitization occurred during the test period), a DDT-treated check tree was compared with an untreated tree. The test was started in February, 1951, when the first DDT application was made, and counts were made each month thereafter until September, when the yellow scale infestation had become so high that commercial fumigation was required. Results (Table 4) show that DDT, as used, had no tendency to cause yellow scale populations to increase more rapidly than was normal. Final populations on the untreated and DDT-treated trees were not significantly different. This test was conducted during that part of the year favorable to yellow scale increase, and the final counts represent a fairly heavy yellow scale infestation. Thus, time was sufficient and conditions were favorable for differences to have become readily evident if DDT had exerted any favorable influence, directly or indirectly.

In the second grove (Kaweah Lemon Co. at Lemon Cove), where the yellow scale infestation was fairly heavy and parasites (dominantly *Comperiella bifasciata*) were just beginning to become abundant, a similar comparison was made between a DDT-treated and an untreated Valencia orange tree. The test was started in April, 1950, when the first DDT application and counts were made. Subsequent treatments and counts were made each month thereafter for about 2 years. Only the pertinent part of the first year's data is presented in table 5, although eventually the scale infestation became much heavier on the DDT check tree than that shown for the month of September.

**Table 4.—Effect of light applications of a low-dosage DDT formulation on yellow scale population increase on Valencia orange trees over an 8 months' period in the absence of effective natural enemies.[a] Peterson grove, 1951.**

| Month of Spray Treatment and Scale Count | Scale Population Density per Tree | |
|---|---|---|
| | Untreated | DDT-Sprayed |
| February | 13 | 7 |
| March | 23 | 4 |
| April | 19 | 13 |
| May | — | — |
| June | 29 | 31 |
| July | 40 | 37 |
| August | 91 | 75 |
| September | 79 | 62 |

[a] An average of 0.5 per cent parasitization by *Aphytis* "A" occurred during the test period. This is inconsequential. No *Comperiella bifasciata* were evident.

**Table 5.—Effect of light applications of a low-dosage DDT formulation on yellow scale population increase on Valencia orange trees over a 6 months' period in the presence of effective natural enemies.[a] Kaweah Lemon Co. grove, 1950.**

| Month of Spray Treatment and Scale Count | Scale Population Density per Tree | |
|---|---|---|
| | Untreated | DDT-Sprayed |
| April | 72 | 59 |
| May | 59 | 47 |
| June | 14 | 75 |
| July | 12 | 112 |
| August | 2 | 109 |
| September | 0 | 105 |

[a] Principally *Comperiella bifasciata*.

These data show that DDT, as used, caused a striking relative increase in yellow scale populations when effective parasites were eliminated or their efficacy was reduced by the toxic effect of DDT on the parasites. The application of this method resulted in a spectacular demonstration of the effectiveness of parasites in the control of yellow scale, comparable to that obtained in many groves with the California red scale.

The parasite *Comperiella bifasciata* on yellow scale appeared to be more resistant to DDT than was *Aphytis* "A" on the California red scale. *Comperiella* usually became relatively abundant as yellow scale population densities became high following several months of the use of DDT sprays, and sometimes would reduce the scale to low levels in spite of the DDT residue. This happened to a lesser extent with *Aphytis* "A." Hence, with yellow scale as with California red scale, the difference between populations on untreated and DDT-sprayed trees is only a conservative measure of the efficacy of the parasites.

Summary.—Experimental comparisons show that light, repeated applications of low-dosage DDT sprays have no stimulating effect of a physiological or physical nature on increase of populations of California red scale, *Aonidiella aurantii* (Mask.), or of yellow scale, *Aonidiella citrina* (Coq.). A relative increase occurs only when effective natural enemies are selectively eliminated by DDT residues. Indications are that DDT actually causes some scale mortality and does not completely eliminate natural enemies; hence, the insecticidal check method presents a conservative rather than an exaggerated measure of the effectiveness of natural enemies of these scales. Various field observations support these conclusions.

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# Relation of Leafhopper Nymphs to the Western X-Disease Virus[1]

H. R. WOLFE[2]

Insect transmission of the western X-disease virus, which causes diseases economically important in peach and cherry, has been demonstrated repeatedly in Utah, Oregon, and Washington (Wolfe *et al.* 1951, Anthon & Wolfe 1951, Kaloostian 1951, Wolfe & Anthon 1953, Nielson & Jones 1954). Insects that have transmitted the virus are the leafhoppers, *Colladonus geminatus* (Van D.), *Scaphytopius acutus* (Say), *Fieberiella florii* (Stal.) and *Keonolla confluens* (Uhl.).

Heretofore none of the experimental transmissions by these insects were made by nymphs, although they were used in many of the tests. In all cases where nymphs of the vectors were involved, they became adults before removal from the test trees. An occasional transmission has been obtained, however, where the insects acquired the virus during the nymphal stage and transmitted as adults (Anthon & Wolfe 1951, Wolfe & Anthon 1953). Evidence reported here indicates that transmission by nymphs of *Fieberiella florii* (Stal), is not exceptionally difficult to obtain, and that it is also possible to obtain transmission of the virus with nymphs of *Colladonus geminatus* (Van D.). Also reported herein is further work concerning transmissions where the vector acquired the virus during the nymphal stage and transmitted it during the adult stage.

METHODS AND MATERIALS.—Test insects used in the experiment were reared on Lovell peach seedling trees in the green house. While most of the leafhopper nymphs were transferred to virus-infected trees in the first to third instars, some of the *C. geminatus* nymphs used in tests hatched from eggs deposited on diseased foliage. Diseased trees used as a source of virus included chokecherry, Lovell peach, or Royal apricot seedlings grown in pots in the greenhouse and infected with the western X-disease virus by graft inoculation. Test trees used were healthy Lovell peach seedlings grown in the greenhouse in 4-inch pots. These were from 3 to 4 inches tall at the time of test insect feedings. The insects were confined to the test trees by plastic cylindrical cages 4 inches in diameter and 6 inches tall. The tops of the cages were made of organdy or cheesecloth to allow adequate ventilation, and the open bases of the cages were pressed lightly into the soil, preventing escape of the leafhoppers.

**Table 1.—Transmissions of the western X-disease virus from infected peach to healthy peach by nymphs of the leafhopper, *Fieberiella florii* (Stal). Wenatchee, Washington, 1952.**

| NYMPHAL INSTARS ON TEST TREES | NO. INSECTS PER TEST | DAYS INSECTS ON INOCULUM | NO. OF TESTS | TRANSMISSIONS |
|---|---|---|---|---|
| 3rd | 1 | 100 | 19 | 3 |
| 4th | 1 | 100 | 16 | 3 |
| 3rd to 4th | 7 | 100 | 2 | 0 |
| 3rd to 5th | 25 | 35 | 1 | 1 |
| 3rd to 5th | 7 | 35 | 1 | 1 |
| 5th | 1 | 35 | 15 | 0 |
| Totals | | | 54 | 8 |

PROCEDURE AND RESULTS.—In a series of 54 tests with *F. florii*, eight nymphal transmissions of the western X-disease virus were obtained (Table 1). One group of nymphs was allowed to feed on infected peach for 35 days and the other for 100 days. They were in the first, second and third instars during the acquisition feeding period on the inoculum source, and in the third, fourth and fifth while on the test trees. Three of the eight transmissions of the virus were by nymphs in the third instar, three were by fourth-instar nymphs, and the remaining two tests involved nymphs in the third, fourth and fifth instars. The shortest period between the first day the leafhoppers were placed on the inoculum source and the last day they were on a test tree which became diseased was 89 days. Duration of nymphal stages of *F. florii* is adequate to permit a long feeding period on inoculum and a long latent period of the virus in the insect. Some of the nymphs which were in the first instar when placed

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on the source of virus did not become adults until 131 days later.

In 106 tests performed in an attempt to transmit the western X-disease virus with *C. geminatus* nymphs, only two transmissions were obtained. In these tests the leafhoppers hatched from eggs deposited on inoculum and were placed on test trees while in the first to fourth instars. Some of the nymphs had been on the source of virus for at least 30 days before being placed on the test tree. In one of the positive tests, 25 first to third instar nymphs, which had developed on western X-diseased foliage, were placed on a healthy test tree and left for a feeding period of 15 days. When they were removed from the test tree, they were in the third to fifth instars. In the other positive test, 25 fourth-instar nymphs which had developed on inoculum, were placed on a test tree and left for 7 days. By then some of the nymphs were in the fifth instar.

The latent period thus far demonstrated for the virus in *C. geminatus* has generally ranged more than 30 days (Wolfe *et al.* 1951), and in many cases it has been 60 days or more. Severin & Klostermeyer (1950) found that the duration of nymphal stages of *C. geminatus* averaged less than 30 days when reared on celery. In the greenhouses at Wenatchee with temperatures ranging from 70° F. to 80° F. only a low percentage of leafhoppers were still nymphs after 30 days. When the temperature was 55° F. to 70° F., however, approximately 25 per cent were still in the nymphal stage at 40 days and approximately 15 per cent were still nymphs within 45 days. In two cases, the nymphal stage extended to 50 days.

Two transmissions with *C. germinatus* nymphs took place at temperatures of 55° F. to 70° F. The period of time from when the leafhoppers hatched on the inoculum until the last day they fed on the test tree was approximately 37 days for one test and 45 days for the other. It is not known whether temperatures have an effect on the latent period of the western X-disease virus in the insect vector. If lower temperature does not lengthen the latent period, however, it is expected that more transmissions of the virus would have been obtained in the series of tests performed under lower temperatures.

A few tests were conducted to obtain nymphal transmissions with *Keonolla confluens* and *Scaphytopius acutus*, with negative results. However, the number of tests performed was not high enough for the results to be of significance. Experiments were also conducted in an effort to obtain added information concerning transmission of the virus by vectors that had acquired the virus during the nymphal stage and transmitted during the adult stage. Of approximately 200 tests with *C. geminatus*, 21 such transmissions were obtained. In two cases the insects fed on the inoculum source and acquired the virus during the first instar. While still in this stage, they were transferred to celery for a holding period until they became adults. In three transmissions, nymphs handled in the same manner acquired the virus during the second instar. In five cases, when nymphs were placed on the inoculum source during the first instar, the virus was acquired before the third instar was completed, because they were removed from the source of virus during that stage. In three other cases, the leafhoppers were placed on the inoculum source during the second and third instars, and the virus was acquired before the fourth instar was completed. In two cases nymphs fed on the source of virus only during the fifth instar, since they were transferred to celery before the adult stage was reached. In six additional cases when the virus was acquired during the nymphal stage, more than one instar was involved in each test. All were still nymphs when moved to celery for a holding period.

Of interest is the fact that *C. geminatus* can acquire the virus during the first and second instars and be capable of transmitting the virus within approximately the same length of time as when the virus is acquired during a later nymphal instar or during the adult stage. In one case where the virus was acquired during the second instar, the virus was transmitted within 28 days from the time the insects were first exposed to the source of virus. This test involved 15 adult leafhoppers that had fed on the source of virus for 5 days. This is a shorter period than usually occurs during transmissions involving adult acquisitions.

In most of the nymphal acquisition tests the Lovell peach seedling test trees showed first symptoms of western X-disease within 30 to 60 days following first exposure to test insects. This is the usual time that symptoms appear under greenhouse conditions on test trees after exposure to insects in adult acquisition tests.

In approximately 50 tests involving *S. acutus* nymphs, only three transmissions were obtained with the leafhoppers acquiring the virus during the nymphal stage and transmitting as adults. In all three cases the virus was acquired during the fifth instar, and the insects were transferred to celery before reaching the adult stage. First symptoms were noted on the Lovell peach seedling test trees approximately 60 days following first exposure of the leafhoppers.

The leafhopper, *F. florii*, being capable of transmitting the virus as a nymph, might be expected to transmit during the adult stage after acquiring the virus while a nymph. One such transmission is on record (Anthon & Wolfe 1951). This species has been very difficult to find during the last 2 or 3 years. Therefore, further tests along this line were not conducted.

More than 100 tests have been performed in an effort to obtain transmission with *K. confluens* adults that had fed on a source of virus as nymphs. Results have been negative, but it should be pointed out that adult acquisitions and transmissions by this species are very difficult to obtain.

Peach trees held as checks for contamination, in numbers approximating the number of test trees in the above experiments, remained healthy. Also there never has been any disease spread by contamination detected in the greenhouses where the work was done through several years of maintaining many hundreds of test trees. Graft transmissions from infected test trees to Lovell peach seedlings in the greenhouse resulted in western X-disease symptoms within 90 days, confirming the transmissions.

DISCUSSION.—It should be pointed out that the work with nymphs of *C. geminatus*, the species considered a primary vector of western X-disease, has been done under laboratory conditions and thus far the importance of stages younger than the adults in field spread of the disease has not been determined. Although they will re-

produce and thrive on diseased peach and cherry when confined to those trees, the writer has yet to witness the natural occurrence of a *C. geminatus* nymph on a peach or cherry tree in the field. The adults of this species of leafhopper are frequently found on stone fruit trees in central Washington, however.

In the fruit-growing area of central Washington, *F. florii* has been found on sweet cherry more often than on any other plant. It is not uncommon to find nymphs of this species on suckers and shoots along the trunk of the tree, especially near the ground. It is not known whether these nymphs hatched from eggs laid on the tree or whether they moved to the tree from the cover crop. This leafhopper has also been collected from alfalfa in stone fruit orchards. It has been found, as a nymph, on sweet cherry trees infected with the western X-disease virus.

The nymphs of *F. florii*, when disturbed, will jump readily, and possibly a nymph which has fed on an infected tree could move through the cover crop to another tree nearby. Since *F. florii* remains in the nymphal stage for a long time, there is a chance that it might move some distance in the cover before it becomes an adult. At least such a nymph which acquired the virus during the nymphal stage may be able to spread the virus after becoming an adult.

SUMMARY.—The western X-disease virus, which causes destructive diseases in peach and cherry, has been transmitted experimentally by nymphs of two species of leafhoppers; *Fieberiella florii* (Stal) and *Colladonus geminatus* (Van D.). Transmissions with nymphs of *F. florii* were less difficult to obtain than with nymphs of *C. geminatus*. Transmissions by both species involved nymphs in the third to fifth instars.

Nymphal transmission tests with *Keonolla confluens* (Uhl.) and *Scaphytopius acutus* (Say) were negative.

Experimental transmissions were also obtained with *C. geminatus*, *S. acutus*, and *F. florii* leafhoppers that had acquired the virus during the nymphal stage and transmitted it during the adult stage. Evidence indicates that all five instars of *C. geminatus* can acquire the virus. Transmission was effected with *S. acutus*, but only with nymphs which acquired the virus during the fifth instar.

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# Residue Studies of Toxaphene, Parathion and Malathion on Some Florida Vegetables[1]

ROBERT E. WAITES and C. H. VAN MIDDELEM[2]

Considerable information appears in the literature on residues of several insecticides which have had wide usage for the past few years. Much of this work has been done on fruit and in areas having quite different climatic conditions than occur in Florida. Residue studies on citrus have been conducted at the Citrus Station at Lake Alfred (Stearns 1949). Residues of toxaphene on tomatoes and lima bean pods are reported in releases by Hercules Powder Co. (1951).

The work described herein was conducted to elaborate on the vegetable residue work previously done in the state (Stasch 1952) and, in view of impending Federal tolerances, to get information on some of the newer insecticides. Vegetable crops were chosen as much as possible for their economic importance in the state. Those insecticides widely used in the state were chosen for analysis; however the availability of reliable and practical analytical procedures was also considered.

Toxaphene, parathion and malathion were selected for the initial residue studies. All the analytical procedures used are specific for the particular insecticide studies, with the exception of toxaphene which was determined by the total-chlorine method. Modification in some of the procedures was found to be necessary because the procedure reported in many cases had not been tried on the particular crop being studied. However, the basic concepts of the method were not altered.

FIELD MATERIALS AND METHODS.—Sixty per cent toxaphene emulsifiable concentrate, 40% toxaphene wettable powder, and 10% and 5% toxaphene dusts were applied to Rutgers tomatoes and blackeye southern peas at two concentrations. Twenty-five per cent para-

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**Table 1.—Effect of formulation of toxaphene and parathion on residues (Expressed in p.p.m.[1]). 1952.**

| TOXAPHENE | | | | | | | PARATHION | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Tomatoes[2] | | | Southern Peas[3] | | | | Okra[4] | |
| | | Harvests | | | Harvests | | | | Harvests | |
| Formulation | Pounds Active Ingredients per Acre | June 23 | June 25 | June 30 | July 16 | July 23 | Formulation | Pounds Active Ingredient per Acre | Aug. 1 | Aug. 6 |
| 40% W.P. | 2.0 | 3.64 | 3.05 | 3.91 | 1.80 | 2.15 | 15% W.P. | 0.30 | 0.27 | 0.20 |
| 60% Emul. | 2.0 | 3.97 | 3.54 | 4.29 | 0.79 | 1.68 | 25% Emul. | 0.30 | 0.28 | 0.29 |
| 10% Dust | 3.5 | 3.54 | 3.23 | 3.53 | 0.66 | 0.57 | 1% Dust | 0.40 | 0.24 | 0.24 |
| 40% W.P. | 1.0 | 2.29 | 2.51 | 1.91 | 1.03 | 1.13 | 15% W.P. | 0.15 | 0.20 | 0.22 |
| 60% Emul. | 1.0 | 2.46 | 2.05 | 2.17 | 0.76 | 1.11 | 25% Emul. | 0.20 | 0.19 | 0.25 |
| 5% Dust | 1.75 | 2.84 | 2.23 | 1.86 | — | — | 1% Dust | 0.20 | 0.19 | 0.20 |
| 10% Dust | 2.5 | — | — | — | 0.99 | 1.47 | — | — | — | — |

[1] Average of three replications.
[2] Application Dates: March 2, 7, 14, 21, 28, June 4, 11, 18, 25.
[3] Application Dates: July 3, 8, 12, 21.
[4] Application Dates: July 4, 8, 12, 21, 30, August 4.

thion emulsifiable concentrate, 15% parathion wettable powder and 1% parathion dust were applied to Clemson Spineless okra at two concentrations. Fifty per cent malathion emulsifiable concentrate and 25% parathion emulsifiable concentrate were applied to cabbage (Resistant Detroit, Early Enkhuizen, and Copenhagen Market). Fifteen per cent parathion wettable powder at three concentrations was applied to Shogoin turnips. (Tables 1 and 2). The crops were grown under standard cultural methods as practiced in Florida. All crops were planted in 4-row plots except okra, which was in 2-row plots. Sprays were applied to tomatoes with a knapsack sprayer calibrated to deliver the desired amount of spray and to southern peas and okra with a Hudson pneumatic sprayer, pumped to 40 pounds pressure at the beginning of the spraying of each plot. Sprays on turnip greens and cabbage were applied with a John Bean "Spartan" sprayer, equipped with 50 feet of hose and a hand boom having a 4-foot handle. The hand boom was fitted with three Hudson adjustable nozzles, No. 4475–52, containing flat fan spray nozzle discs No. 2253. The nozzles on the boom were spaced so that one was above and one was each side of the row. All dusts were applied with a Niagara Cyclo-Junior hand duster, calibrated to deliver the desired amount of dust.

SAMPLING AND EXTRACTING.—The manner and size of sample taken for analysis depended on the particular crop under study.

*Tomatoes.*—Uniform medium-sized fruit in green-ripe and light-pink stage of maturity were taken for extracting. The tomatoes were not washed but handled normally otherwise. Approximately 1500 grams were extracted with 1000 ml. of benzene for 15 to 20 minutes. Two 450 ml. aliquots were saved for analysis.

*Okra.*—The entire plot was harvested and well mixed. A 500-gram sample, composed of whole pods, was saved from each plot and extracted with 500 ml. of benzene.

*Southern peas.*—The entire plot yield was harvested and placed in a rotary cutter. A 1000-gram sample was selected from the cut gross sample and extracted with 1000 ml. of benzene for 30 minutes.

*Turnip greens.*—A 20-pound paper bag was filled with

**Table 2.—Effect of interval on residues (Expressed in p.p.m.[1]). 1953.**

| VEGETABLE | INSECTICIDE TREATMENT | OUNCES ACTIVE INGREDIENT PER ACRE | TIME INTERVAL SINCE LAST APPLICATION | | | | |
|---|---|---|---|---|---|---|---|
| | | | 4 Hrs. | 24 Hrs. | 48 Hrs. | 3 Days | 7 Days |
| Cabbage[2] | 50% malathion Emul. | 10.1 | 14.7 | 13.3 | 8.6 | — | 2.4 |
| | | 20.2 | 45.7 | 30.4 | 28.6 | — | 8.7 |
| | | 30.3 | 91.3 | 72.0 | 55.0 | — | 24.8 |
| Turnip greens[3] | W. P. parathion 15% | 1.76 | 7.1 | 5.0 | — | 2.0 | 0.8 |
| | | 2.4 | 15.1 | 7.0 | — | 2.6 | 1.5 |
| | | 4.8 | 31.0 | 10.3 | — | 4.7 | 2.6 |
| Cabbage[4] | 50% malathion Emul. | 16.66 | 41.3 | 31.6 | — | 10.8 | 0.1 |
| | Malathion and DDT | 16.66 | 41.1[5] | 32.6 | — | 13.0 | 0.2 |
| | Emul. parathion 25% | 4.4 | 10.0 | 7.1 | — | 1.5 | 0.6 |
| | Parathion and DDT | 4.4 | 11.8[5] | 8.6 | — | 2.5 | 0.3 |

[1] Average of three replications.
[2] Application dates: Feb. 16, 23, Mar. 2, at Gainesville.
[3] Application dates: May 18, 22, 26, at Gainesville.
[4] Application dates: Jan. 2, 13, 23, 30, Feb. 6, 13, 20, 27, Mar. 17 at Hastings.
[5] Residues are malathion and parathion only, DDT not included.

tops cut at random in each plot. Tops were mixed and a 600-gram sample taken at random and extracted with 750 ml. of carbon tetrachloride for 30 minutes.

*Cabbage.*—Five mature heads were harvested at random from each plot. The outer head leaves were composited and mixed. A 1000-gram sample was extracted with 1000 ml. of carbon tetrachloride or benzene for 30 minutes. The inner head was discarded.

LABORATORY PROCEDURE.—After tumbling 30 minutes on horizontal rotating rollers at approximately 32 r.p.m. the samples were filtered and a known volume saved for laboratory analysis. Generally between 250 and 400 ml. aliquots were used. Duplicate aliquots were saved in all experiments. The residue determinations recorded in tables 1 and 2 are corrected figures obtained by subtracting the readings of samples of untreated check plots from those of the samples of the various treated plots. The usual procedure in the laboratory was to concentrate the above aliquots to approximately 10 ml. volume by a gentle stream of air and moderate heating. After concentration the chemical steps utilized to determine the actual residue depended on the particular insecticide under study.

For malathion determinations the colorimetric method was used (Norris *et al.* 1954). The Averell-Norris method (modified) was followed in ascertaining parathion. Total chlorine was determined in estimating toxaphene residues by the use of an amperometric titration technique. The analysis was carried out by the sodium-isopropyl alcohol reduction procedure.

RESULTS AND DISCUSSION.—Six treatments of toxaphene were made to tomatoes for a total of nine applications. The tomatoes were harvested and sampled 5 and 7 days after the last application. The average residues of toxaphene for three replicates of unwashed tomato fruit are shown in table 1. Amounts of residues for individual plots ranged from 0.72 to 5.72 p.p.m. The total rainfall recorded from May 2 to June 30 was 9.09 inches. In addition 5.00 inches of irrigation water was put on the tomatoes by means of rotating sprinklers. The average mean temperature was 77.5° F. There was little difference between formulations and amounts of residues found in this experiment. The residues do not seem particularly high after allowing only 5 to 7 days of weathering, and in comparison with a federal tolerance of 7.0 p.p.m. for toxaphene. Another 7 days would undoubtedly reduce the amounts of residues even further. The amount of water which fell on the tomato plants was probably a major factor in the reduction of residues.

Six treatments of toxaphene plus an untreated check were replicated three times on southern peas for a total of four replications. Amounts of residue for individual plots ranged from 0.49 to 1.88 p.p.m. and 1.11 to 2.27 p.p.m. 4 and 2 days after the third and fourth applications respectively. The highest residue in the first harvest, made 4 days after the third application, was 1.80 p.p.m. (average of 3 replicates), taken from plots that had received 2 pounds active 40 per cent wettable powder. The other treatments (Table 1) composed of 60 per cent emulsion and 10 per cent dust resulted in slightly lower residues averaging close to 1 p.p.m. The second harvest resulted in slightly higher residues than the first. This was probably due to the fact that the harvest was made only 2 days later and an additional application had been made, thereby resulting in a greater accumulation of residue. The pods from the second harvest had 2 days less weathering than the first harvest. The total rainfall recorded during this experiment was 2.78 inches. Irrigation water was not put on the peas after the treatments were started. The average mean temperature was 82.5° F. The residues on southern peas do not appear to be excessively high when it is considered they were sampled 2 and 4 days after treatment. Residues were well within the federal tolerance of 7.0 p.p.m. for toxaphene.

Six treatments of parathion and untreated check were replicated three times on okra. Harvests were made 48 hours after the fifth and sixth applications. Parathion residues (Table 1) on okra were found to be very low, ranging from 0.18 to 0.32 p.p.m. on individual plots. It may be noted that there is very little difference between the formulations in the amounts of residue. The very low residues on okra probably may be explained, in part at least, by the rapid growth of okra. Because of this there is little possibility that an accumulation of more than one or two applications could occur on the marketable pods. The fact that parathion is not a long lasting residual insecticide would also account in part for the low residues. The average mean temperature during treatment was 82.7° F. and the total rainfall recorded was 4.10 inches. These two weather factors undoubtedly aided in the rapid reduction of parathion residues.

Several experiments were set up to study the initial residue concentrations and rate of disintegration with time. In one experiment at Gainesville, 50% malathion emulsifiable concentrate was applied to cabbage at the rates of 10.1, 20.2 and 30.3 ounces of active ingredient per 100 gallons per acre, for a total of three applications. Harvests were made 4, 24, 48 hours and 7 days after the last application. The average residues for three replications are shown in table 2. Residues for individual plots ranged from 12.0 to 122.5 p.p.m. and from 1.2 to 39.0 p.p.m. 4 hours and 7 days after the last application, respectively. It may be noted from the table that malathion residues break down rather rapidly at all three treatment levels. During the first 48 hours after application approximately 40 per cent of the malathion residues had dissipated. After 7 days normal weathering approximately 80 per cent of the residue had disappeared. The total rainfall recorded during treatment was 0.21 inch. No irrigation water was put on the plants while they were under treatment. The average mean temperature was 62.8° F.

A similar experiment was conducted at Hastings, in cooperation with Dr. T. M. Dobrovsky, Assistant Entomologist at the Potato Investigations Laboratory, to determine the rate of breakdown of both malathion and parathion with and without the presence of DDT. Fifty per cent malathion emulsifiable concentrate, was applied at the rate of 16.66 ounces and 25% parathion emulsion at 4.40 ounces of active material per 100 gallons per acre for a total of nine applications. Harvests were made 4, 24 hours, 3 and 7 days after the last application. The results, which are averages of three field replications, are shown in table 2.

In this experiment, 68 per cent of the malathion residues had dissipated after 3 days and 99 per cent after 7

days. Parathion residues dissipated 85 per cent after 3 days and 97 per cent after 7 days. No attempt is made to compare the reduction of residues at Gainesville and Hastings because both intervals between applications and dosage rates were different. For the same reasons no comparisons are made between parathion and malathion.

An interval of 28 days lapsed between the extraction of samples and the chemical determinations of residue for the Gainesville experiment and 7 days for the Hastings experiment. In an earlier experiment with snap beans, the authors found no significant reduction in the amount of malathion in the extract samples stored for 20 and 40 days at room temperature, 36° F. and 0° F.

A study of parathion residues was made on turnip greens in an endeavor to further determine initial concentrations and rate of breakdown. Fifteen per cent parathion wettable powder was applied at the rates of 1.76, 2.4 and 4.8 ounces active material per 100 gallons per acre for a total of three applications. Results are shown in table 2. Each figure is an average of three replications. Residues for individual plots ranged from 6.33 to 33.27 p.p.m. and from 0.69 to 3.09 p.p.m. 4 hours and 7 days after the last application, respectively. In comparison with the federal tolerance of 1.0 p.p.m., parathion residues were high for the first 24 hours. However, the initial rate of breakdown is quite rapid, 70 to 85 per cent 3 days after the last application. After 7 days of weathering, residues were reduced 90 per cent. The total amount of rainfall recorded during treatment was 0.83 inch and the average mean temperature was 82.4° F. The high temperatures probably were a contributing factor in the rapid reduction of the parathion residues.

SUMMARY AND CONCLUSION.—The amounts of residue varied on tomatoes, southern peas, and okra, however there was very little difference in amounts of residue when using emulsifiable concentrate, wettable powder or dust. Residues on these crops do not seem excessively high considering the short period of weathering before harvesting. An additional 7 days of weathering would reduce amounts of residues further. The very low residues on okra can be accounted for, in part, by rapid growth resulting in little possibility that an accumulation of more than one or two applications could occur on marketable pods.

Malathion residues on cabbage broke down quite rapidly, 40 per cent after 48 hours. After 7 days of normal weathering approximately 80 per cent of the residue had disappeared. Parathion residues on cabbage dissipated 85 per cent after 3 days and 97 per cent after 7 days.

Parathion residues on turnip greens were reduced 70 to 85 per cent after 3 days weathering and 90 per cent after 7 days. The time interval between the insecticide application and harvest, amount of rainfall and temperature were factors which influenced amounts of residues on the crops studied.

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# Meadow Spittlebug Control by Pre-emergence Treatment[1]

J. T. MEDLER[2]

The meadow spittlebug, *Philaenus leucophthalmus* (L.) is readily controlled by an application of chlorinated hydrocarbon insecticide when the spittle masses are observed. In Wisconsin, the alfalfa is often 18 to 24″ tall when the spittle masses become conspicuous, and insect injury may have already occurred. The control of newly hatched nymphs by a pre-emergence application of insecticide would be desirable because the alfalfa is only 3 to 9″ tall at time of spittlebug emergence, and the subsequent growth would not be injured. Also, the possibility of insecticide residue at harvest time would be materially reduced by the longer period of weathering and greater dilution by more plant growth.

BIOLOGY.—Infestations of the meadow spittlebug are initiated each year by the overwintering eggs. The hatching date of eggs can be predicted by the heat unit method described by Medler (1955). Weaver & King (1954) described the egg masses and their common deposition site in the stubble of a grain companion crop. In Wisconsin, a search in early spring will reveal the egg packets in grain stubble of first year alfalfa fields. However, in older alfalfa fields, which do not have grain stubble, the overwintering eggs are not easily found. On the basis of greenhouse tests reported by Weaver and King it might be expected that the eggs would be found attached to alfalfa stems with or without a leafy covering.

During the course of our research on the spittlebug, T. R. Chamberlin and I examined many dead alfalfa stems in the spring and never found egg packets. Collections of stems, trash, plant crowns, and soil were made during 1947, 1948, and 1949 in fields where large numbers of nymphs later appeared. For example, in 1947 the sam-

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ples totaled 1185 alfalfa stems or parts of stems. This material was carefully examined under magnification in the laboratory. The soil was mixed with water or saline solution and the floating material screened and studied. The examination of the samples did not reveal eggs in numbers that could be correlated with the high populations known to occur. The relatively few eggs which were found were incubated, but among several insect species only one spittlebug was hatched, and this was from an egg found in soil.

Attempts also were made to locate eggs by indirect methods. Stems collected in the field were observed in the laboratory for egg hatching, but the method did not reveal the presence of eggs.

In 1950, the surface trash, plant parts and top ½ inch of soil in 20″×40″ rectangles were sampled separately. A laboratory examination of stems revealed no spittlebug eggs. One-half of the soil was examined by flotation, washing and sieving, but no eggs were found, as was true also for the microscopic examination of one-half of the surface trash. The other halves of the soil and surface trash each were placed in aluminum dish pans in a greenhouse and sown to oats. The oats sprouted in both pans but did poorly in the trash. One week after the experiment was set up it was noticed that newly-hatched spittlebugs were forming dew-like masses on the oats in the pan with soil but not in the pan with trash. It was evident that spittlebug eggs were in the surface soil but were difficult to discover by flotation, sieving and washing. Also in 1950 a careful search was made of stems and trash on the surface of the soil in alfalfa fields. A single egg capsule was picked up from the soil. This was the first capsule found during a 4-year search. Therefore it was concluded that the egg packets are broken up during winter and eggs become scattered on the soil surface no matter where the spittlebug eggs are laid in second year and older alfalfa fields.

Laboratory tests were made in 1948 on the rate of travel by first instar nymphs. It was determined that they move at the average rate of 2 inches per minute on smooth surfaces and 1.6 inches per minute on alfalfa stems. These tests and other observations in the field demonstrated that the young nymphs can move about at a relatively fast rate. Observations in the field have established that the young spittlebugs are first found under stipules of leaves low on alfalfa stems. From that site they move upward toward the tops of stems, where they tend to become concentrated. In some instances they move downward from established spittle masses, as was observed following a change in the prevailing cool weather to a hot-drying windy spell. The movements of the spittlebug up and down alfalfa stems probably explains in large part why residual chlorinated hydrocarbon insecticides are generally effective for the control of this insect, as reported by Medler (1954) and many other investigators.

CONTROL TESTS.—At the Sheboygan County farm in 1951, DDT, toxaphene and dieldrin were applied at 10 gallons per acre with a ground sprayer when the alfalfa was 1 to 3″ tall and spittlebugs were not yet hatched. The same insecticides were applied in adjacent plots 2 weeks later when the alfalfa was 10″ tall and the spittlebugs had hatched. Control data are given in table 1. It was concluded that the pre-hatch spraying with emulsion gave inadequate control.

Marshall & Gyrisco (1951) applied lindane at weekly intervals to determine the earliest pre-emergence dusting date for effective control, and found that the earliest effective dusting date was 1 week before egg hatching. Weaver & King (1954) found that best control was obtained with BHC and toxaphene at 2 weeks after hatch, when compared with treatments at first hatch and 1 week after.

It was concluded by the writer that conventional emulsion sprays or dust treatments are not as effective when applied at pre-emergence as when used post-emergence. However it seemed desirable to conduct further tests with a granulated formulation, because of the control shown by this type of insecticide for insects that spend part of their life cycle on or in the soil. It was postulated that nymphs move about on the surface of the soil in order to establish themselves on alfalfa stems, and granulated insecticides on the soil might be effective for their control.

In 1953, two first year alfalfa fields of uniform stand were selected in Washington County. The fields were 10 and 13 acres, respectively. About 1 week prior to the first appearance of nymphs one-third of each field was treated by airplane with BHC granules 1.2% gamma isomer at a rate of 0.3 lb. gamma isomer of BHC per acre. The granules were 30/60 AA attapulgus clay impregnated with a xylene solution of the insecticide. On May 19, when spittlebugs were just hatching, another one-third of the field was treated by an airplane at the rate of 4.5 gallons of emulsion spray with 1 lb. of methoxychlor per acre. The middle one-third of each field was left untreated. Control data are given in table 2. Although

**Table 1.—Control of spittlebugs in 1/10-acre plots of alfalfa treated with emulsion sprays at pre- and post-emergence dates, 1951.**

| Insecticide and Tech. Amt./Acre | Per Cent Reduction from Untreated Adjacent Check[a] | |
|---|---|---|
| | May 4 (Pre-Emergence) Treatment | May 18 (Post-Emergence) Treatment |
| DDT 1 lb. | 61.8 | 89.9 |
| Toxaphene 1 lb. | 73.7 | 100 |
| Dieldrin ¼ lb. | 71.1 | 98.6 |

[a] Based on counts of spittlemasses made on June 12.

**Table 2.—Control of spittlebugs in alfalfa treated by airplane with insecticides at pre- and post-emergence dates, 1953.**

| Treatment | Per Cent Infested Stems on June 11 | | Per Cent Reduction from Untreated Check | |
|---|---|---|---|---|
| | Field 1 | Field 2 | Field 1 | Field 2 |
| BHC[a] | 1 | 0 | 97.5 | (100) |
| Methoxychlor[b] | 4 | 0.3 | 90.0 | ( 70) |
| Untreated check | 40 | 1 | | |

[a] Applied 1.2% granules May 12 (pre-emergence) at 0.3 lb. gamma isomer per acre.
[b] Applied May 19 (post-emergence) in emulsion form at 1 lb. per acre.

spittlebugs in the checks were nearly absent in one field and were not abundant in the other field, the granulated formulation of BHC was promising as a pre-emergence method of control. The extremely low population in the check necessitated a change in my usual method of counting masses on 100 stems. I walked through the plots and bent over 100 times at random to part the alfalfa stems. In the check there was a mass seen every time, in the BHC plot no masses were visible (the plot was exceptionally clean), and in the methoxychlor plot a mass was visible 3 out of every 100 examinations.

In 1954, 2 fields in Ozaukee County, 3 in Washington County, and 1 in Sheboygan County were selected for the tests. Each field was divided into 4 equal plots, which ranged in size in the 6 fields as follows: 1.9, 2, 2.6, 3.4, 3.75, and 4.7 acres. One plot was left untreated and granules of BHC (1% gamma isomer), dieldrin and heptachlor were applied to the other three plots by airplane at the rate of 30 lbs. per acre. The treatments were randomized in each field. The insecticides were impregnated on 30/60 AA attapulgus clay as in 1953. An application in early May was planned on the basis of the heat unit method of predicting the egg hatch, but an unexpected delay in obtaining the airplane caused a week's postponement. When the insecticides were applied on May 12, the spittlebugs had just started to hatch in four of the fields. Therefore only the two fields in Ozaukee County actually had a pre-emergence application.

The control data are given in table 3. Because of the very low infestation in the check in the Gengler field, this test was omitted in the statistical analysis of the data. Using an angular transformation in the analysis of variance and Duncan's (1951) multiple range test it was shown that BHC was significantly better than dieldrin and heptachlor. It will be noted in table 3 that all fields had a relatively low spittlebug population in the checks. This is consistent with a downward trend in infestations first noticed in 1952 and commented upon by Medler *et al.* (1953). The same condition held true also in 1953 as shown in table 2.

**Table 3.—Control of spittlebugs in alfalfa treated with granulated insecticides, 1% active ingredient.[a] 1954.**

| Farm and Country | Spittle Masses per 100 Stems in Untreated Check | Per Cent Reduction from Untreated Check | | |
|---|---|---|---|---|
| | | (Gamma Isomer) | Dieldrin | Heptachlor |
| Prange, Sheboygan Co. | 24.5 | 98.0 | 83.7 | 93.9 |
| Krueger, Ozaukee Co. | 34.0 | 98.5 | 66.2 | 64.7 |
| Kohlwey, Ozaukee Co. | 21.5 | 97.7 | 90.7 | 95.3 |
| Gengler, Washington Co. | 4.0 | 87.5 | 0 | 62.5 |
| Esselman, Washington Co. | 39.0 | 98.7 | 96.2 | 88.5 |
| Mayer, Washington Co. | 44.5 | 86.5 | 49.4 | 84.3 |
| Average | | 94.4 | 64.3 | 81.5 |
| Corrected average (Gengler omitted) | | 95.9 | 77.2 | 85.3 |
| Duncan's multiple range test[b] | | — | — | |

F values:
Treatments 11.36**
Replicates 4.00*

[a] Applied May 12 at 0.3 pound per acre; insects sampled June 15.
[b] Any two treatments means not underscored by the same line are significantly different.

CONCLUSIONS.—In the spring newly-emerged spittlebugs move across the surface of the soil in order to reach the alfalfa stems where they become established. In first year alfalfa fields the nymphs may hatch from eggs in packets deposited in the grain stubble. In second year or older alfalfa fields the nymphs probably hatch from eggs scattered about on the surface of the soil.

The nymphs were controlled effectively with granulated BHC applied to alfalfa fields prior to the hatch of eggs. Granulated dieldrin and heptachlor were not as effective as BHC when applied at the same dosage. The results raise a question of whether the control obtained with BHC is both by a contact action and a fumigating action on the young nymphs.

The residue hazard of an insecticide should be reduced to insignificance by pre-emergence applications of granulated insecticide, since the plants are small and the granules largely fall to the ground. However, the practicality of the pre-emergence applications is doubtful until a way of predicting the insect infestation can be developed.

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# Effect of Some Organic Insecticides on the Population Levels of the Serpentine Leaf Miner and Its Parasites[1]

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During the past 8 years a serpentine leaf miner, *Liriomyza subpusilla* (Frost),[2] has developed as a major insect pest of peppers, cantaloupes, tomatoes, and blackeyed peas. Although controlled in California with aldrin and dieldrin (Wilcox & Howland 1952) and in Texas with parathion (Wene 1953), Wene (1953) showed that dieldrin and parathion also affected the population levels of the leaf miner's parasites. Hill & Taylor (1951) showed that DDT killed parasites of the serpentine leaf miners and had no effect on the miner population. Four experiments were conducted to determine the effect of some commonly used insecticides on the population levels of the serpentine leaf miner and its parasites.

PROCEDURE.—The first experiment was conducted in a field of blackeyed peas. Each plot was 1 acre in size and each treatment was replicated twice. The treatments, shown in table 1, were applied with rotary hand dusters at approximately 25 pounds per acre on March 28, April 4, 11, 20, 29, and May 7, 1953. Populations of leaf miners and parasites were determined by rearings from infested leaves which had been placed in 1-quart ice cream cartons fitted with glass vial windows. On April 3, one day before the first treatment application, 30 infested leaves were picked at random from the entire area for preliminary population determinations. Then on April 23, and again on May 12, 10 infested leaves were selected at random from each plot for population determinations.

**Table 1.—Effect of insecticidal dusts on the population levels of a serpentine leaf miner and its parasite on blackeyed peas.**

| TREATMENTS[a] | AVE. NO. PER LEAF | |
|---|---|---|
| | Leaf Miners | Parasites |
| Before treatments, entire area | 0.5 | 0.1 |
| After 4 Applications | | |
| 2.5% Aldrin | 6.3 | 0.5 |
| 5.0% DDT | 2.8 | 1.4 |
| Untreated | 2.3 | 1.6 |
| After 6 Applications | | |
| 2.5% Aldrin | 12.7 | 3.2 |
| 5.0% DDT | 7.4 | 1.0 |
| Untreated | 4.5 | 1.8 |

[a] Treatments were applied on March 28, April 4, 11, 20, 29 and May 7, 1953.

The second experiment was conducted in a tomato field. Each plot was 0.75 acre in size with each treatment being replicated four times. The treatments, shown in table 2, were applied with rotary hand dusters at approximately 25 pounds per acre on April 10, 18, 24, and May 2, 1953. Eight days after the final treatment application 10 tomato leaves were picked at random from each plot and placed in the ice cream carton rearing cages for population determinations.

**Table 2.—Effect of insecticidal dusts on the population levels of a serpentine leaf miner and its parasites on tomatoes.**

| TREATMENTS[a] | AVE. NO. PER LEAF | |
|---|---|---|
| | Leaf Miners | Parasites |
| 5.0% DDT | 12.7 | 2.9 |
| 5.0% TDE | 10.2 | 0.9 |
| 20% Toxaphene | 8.0 | 0.3 |
| Untreated | 8.6 | 4.4 |

[a] Applied on April 10, 18, 24, and May 2, 1953.

The third experiment was conducted in a cantaloupe field which had been planted in rows spaced 6 feet apart. A plot consisted of a single row of cantaloupes 30 feet in length. Each of the treatments, shown in table 3, was replicated three times. The insecticides were applied with a 3-gallon garden sprayer at the rate of 100 gallons of spray per acre. Table 3 shows the rates at which the insecticides were used. Treatments were applied on March 12, 16, 20, 24, April 3, and April 8, 1954. One week after the final treatment application five infested leaves were picked at random from each plot for population determinations.

The fourth experiment was conducted in a watermelon field adjacent to the cantaloupe field. The plots were similar in size and each treatment was replicated three times. The treatments, shown in table 4, were applied in the same manner as in experiment 3. These treatments were applied on March 16, 20, 24, 29, April 3 and 8, 1954. One week after the final treatment application five leaves were picked at random from each plot and the population of leaf miners and their parasites determined.

**Table 3.—Effect of insecticidal applications on the population levels of a serpentine leaf miner and its parasites found on cantaloupes.**

| TOXICANT PER 100 GALLONS WATER[a] | NUMBER PER LEAF | |
|---|---|---|
| | Leaf Miners | Parasites |
| 0.25 lb. parathion | 0.5 | 0.0 |
| 0.25 lb. lindane | 0.9 | 0.8 |
| 0.4 lb. endrin | 1.1 | 0.3 |
| 0.38 lb. dieldrin | 1.1 | 0.3 |
| Untreated | 0.8 | 1.7 |

[a] Applied on March 12, 16, 20, 24, 29, April 3 and 8, 1954.

DISCUSSION.—The following parasites were reared from the leaves collected in the four experiments:

[1] Accepted for publication April 4, 1955.

[2] Identified as a single species by Dr. Kenneth E. Frick, Irrigation Experiment Station, Prosser, Washington.

*Diaulinopsis callichroma* Cwfd.[3]
*Derostenus variipes* Cwfd[3]
*Zagrammosoma sp*[3]
*Opius dimidiatus* Ashm.[4]
Cynipid, undescribed[4]

No attempt was made to determine the abundance of the various parasites, but observations indicated that *Diaulinopsis callichroma* Cwfd. was the most numerous parasite recovered.

In experiment 1, the first population record was taken when the blackeyed peas were still in the cotyledon stage of growth. The infestation was just starting and the leaf miners were more abundant than the parasites. The data also show that the highest leaf miner infestation was found in the aldrin-dusted plots. The final examination showed that 78 per cent more parasites were recovered from the plots treated with aldrin than from the untreated plots, but leaf miner population in the aldrin-treated plots was 182 per cent greater than that in the untreated plots, indicating that the aldrin applications created an environment which favored the development of leaf miner populations. The data in table 1 show that the application of DDT dust encouraged leaf miner infestations and also reduced the number of parasites. It is interesting to note that on May 20, when the blackeyed peas were being harvested the plants in the aldrin and DDT plots had shed most of their leaves due to leaf miner injury whereas no leaf shedding was noticed in the untreated plots. This shows that under natural conditions parasites may control a leaf miner infestation. The data from experiment 1 indicated that the improper use of insecticides can create a leaf miner problem by killing the leaf miner's parasites.

**Table 4.—Effect of insecticidal applications on the population levels of a serpentine leaf miner and its parasites found on watermelons.**

| Toxicant per 100 Gallons Water[a] | Number per Leaf | |
|---|---|---|
| | Leaf Miners | Parasites |
| 0.25 lb. parathion | 0.2 | 0.3 |
| 0.25 lb. lindane | 2.0 | 0.6 |
| 0.38 lb. dieldrin | 1.2 | 0.7 |
| Untreated | 0.8 | 0.7 |

[a] Applied on March 16, 20, 24, 29, April 3 and 8, 1954.

Treatments in the second experiment were started when small fruit was first noticed on the tomato plants. During the time of the experimentation the tomato plants were suffering from a lack of moisture due to the drought prevailing at that time. The greatest leaf miner infestations were found on the DDT and TDE plots, both having a lower parasite population than on the untreated plots, indicating that the reduction in parasites allowed the leaf miner population to develop faster. The 20 per cent toxaphene dust reduced the parasite population more than DDT or TDE. However, the leaf miner population was lower than in the untreated plots indicating that toxaphene gave some leaf miner control, although not enough to be important economically.

The treatments in experiments 3 and 4 were started when the plants were still in the cotyledon stage of growth. Final data were taken before the plants had started to set fruit. In this area severe leaf miner infestations start developing only after the plants have set fruit. The data in tables 3 and 4 show that parathion sprays kept both the leaf miner and its parasites at a low population level. The data also show that parathion was more effective than lindane, endrin or dieldrin in reducing populations of parasites of the serpentine leaf miner. The data also show that applications of endrin, dieldrin, and lindane tend to increase the population of leaf miners, probably by controlling the parasites.

SUMMARY.—Insecticidal dusts containing DDT, aldrin and TDE reduced the population of parasites of a serpentine leaf miner, *Liriomyza subpusilla* (Frost), and thereby accentuated the leaf miner problem. The data showed that toxaphene reduces populations of the parasites of the serpentine leaf miner, but the leaf miner infestation did not increase indicating that toxaphene gave some degree of control of this pest.

In the high volume spray experiments parathion reduced the numbers of both the leaf miner and its parasites. The data indicated that lindane, endrin, and dieldrin reduced the parasite population, but were not as toxic to the parasites as parathion. The leaf miner population was greater on the dieldrin-, endrin-, and lindane-treated plots indicating that these insecticides create an environment favorable for leaf miner development by reducing the parasite population and not being effective against the leaf miner.

A large scale experiment showed that parasites were effective in controlling the leaf miner.

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[3] Identified by B. D. Burks, Insect Identification and Parasite Introduction Section, U.S.D.A.
[4] Identified by C. F. W. Muesebeck, Insect Identification and Parasite Introduction Section, U.S.D.A.

# SCIENTIFIC NOTES

## Codling Moth Resistance to DDT in New York[1]

E. H. Glass and Bart Fiori, *N. Y. State Agr. Expt. Sta., Geneva*

During the past 3 years there have been many reports of increased codling moth activity in commercial apple plantings from several parts of the country including New York (Hamilton *et al.* 1954). In most instances, favorable codling moth weather and laxity in spraying have been found to be the primary causes of the trouble. However, Cutright (1954) reported that a strain of codling moth in Hamilton County, Ohio, was definitely resistant to DDT.

In an orchard near Lockport, N. Y., this insect has become an important apple pest during the past 3 years. In the years prior to the introduction of DDT, lead arsenate had become less and less effective in this orchard until the early 1940's when it was failing to give commercial control. The grower switched to DDT in 1946 and had excellent results for the next 6 years. At least one of these years (1949) was quite favorable for codling moth development. In 1952, late second brood activity caused a noticeable amount of damage. On June 18, 1953, it came to the writers' attention that the first brood was not being controlled by a fresh deposit of a DDT-parathion spray mixture applied on June 16. A second cover spray using 2 pounds of 50 per cent DDT was applied over the entire 20-acre block of McIntosh on June 21. This stopped further activity for about 1 week.

For the remainder of the season three spray formulas were tested, each being replicated four times. The grower did the spraying with a Bean Speed Sprayer at dilute concentration using approximately 17 gallons per tree. Such treatment is considered commercially adequate for this area and type of tree. Sprays were applied as often as needed as indicated by fresh larval activity. The spray dates were June 29, July 7, July 15, August 1, August 8, August 15 and August 27 for a total of nine cover sprays.

Results for the season are given in table 1. The number of stings, worms per 100 apples and per tree were much above the normal for this area where it is customary to apply four or five DDT cover sprays at 12- to 14-day intervals and obtain almost perfect codling moth control.

In 1954 a detailed experiment was carried out in this orchard using single tree plots replicated eight times in controlled randomized blocks. Spraying was done at 550 pounds pressure with a hand gun using 25 to 30 gallons per tree. Lead arsenate at 3 pounds per 100 gallons was used in the petal fall and 10-day sprays over the entire block. Six cover sprays were applied in the experimental block, as follows: June 11, 21, July 1, 15, August 3, and 16.

Similar experimental technics (Glass 1954) were used in two other western New York orchards. Only five cover sprays were applied. The results of comparable treatments for the three experiments are given in table 2. It is readily apparent that the infestation levels in the Geneva and Sodus orchards were much heavier than that in the Lockport block, a condition brought about by improper spraying during preceding seasons. However, control with DDT, methoxychlor and Dilan in the Lockport block was inferior to that in the other two. Control with lead arsenate, parathion, Diazinon and the DDT-Malathion combination was in proportion to the infestations existing in the various orchards. It should also be noted that control with methoxychlor was significantly inferior to lead arsenate in the Lockport test, whereas in tests at Geneva during four seasons, including 1954, there has been on the average seven times as many worms with lead arsenate as with methoxychlor.

During the summer, larvae of the Lockport and Geneva codling moth strains were tested for DDT tolerance using the technic of allowing newly hatched larvae to crawl from cellophane strips where eggs were deposited to apples suspended from racks in the insectary. The apples were sprayed a few hours before affixing the egg using a hydraulic orchard sprayer and spray gun. The results are given in table 3. A difference in ability to enter untreated fruits was observed between the two populations but it was not as great as on the DDT treated apples. The per cent control has been calculated using the Abbott formula to adjust for possible differences other than DDT tolerances. It is evident that the two populations responded quite differently to the DDT treatment.

**Table 1.—Codling moth control in a Lockport orchard, 1953.**

| Material | Pounds per 100 Gallons | Per Cent Stung | Worms per 100 Apples | Worms per Tree |
|---|---|---|---|---|
| 50% DDT | 2 | 8.2 | 4.8 | 171 |
| 50% DDT | 3 | 9.3 | 3.9 | 115 |
| DDT-parathion[a] | 2½ | 9.6 | 3.3 | 92 |

[a] Black Leaf 253, product of Virginia-Carolina Chemical Corporation, containing 25% DDT and 3% parathion.

**Table 2.—Codling moth control in three New York orchards, 1954.**

| Material | Pounds per 100 Gallons | Worms per 100 Apples | | |
|---|---|---|---|---|
| | | Geneva | Lockport | Sodus |
| Check | — | 244 | 40 | 228 |
| 50% DDT | 2 | 0.9 | 2.3 | 0.8 |
| 50% methoxychlor | 2 | 4.4 | 15.2 | — |
| 25% Dilan | 4 | (0.3)[a] | 4.0 | — |
| Lead arsenate | 3 | 30.1 | 6.0 | — |
| 15% parathion | 2 | 5.0 | 1.2 | — |
| 25% Diazinon | 2 | 1.3 | 0.5 | — |
| L.S.D. at 5% level | | 5.0 | 3.2 | |

[a] Dilan was not tested in Geneva in 1954 but in several previous tests control has equalled DDT. This figure was obtained in a 1952 test.

**Table 3.—Insectary evaluation of the Geneva and Lockport codling moth populations, 1954.**

| Test No. | Per Cent Control with 2 Ounces of 50% DDT per 100 Gallons | |
|---|---|---|
| | Geneva | Lockport |
| 1 | 96 | 75 |
| 2 | 89 | 49 |
| 3 | 91 | 47 |
| 4 | 95 | 62 |
| 5 | 90 | 55 |
| Average | 92 | 58 |
| Total eggs | 830 | 616 |

[1] Journal Paper No. 999, New York State Agricultural Experiment Station Geneva, New York, March 23, 1955.

CONCLUSIONS.—The data from field and insectary tests show that there is a difference between the response to insecticides of codling moth in the Lockport and two other New York orchards. It appears likely that this difference is due to the development of resistance in the Lockport strain. The fact that DDT was successfully used for 6 years and has been failing for the last two seasons in this orchard lends support to this thesis. Assuming the responses found are due to resistance then it is small compared to that reported by Cutright (1954).

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## The Separation of the Adults of *Acontia dacia* Druce from Related Species[1, 2]

E. L. TODD, *Entomology Research Branch, Agr. Res. Serv., U.S.D.A.*

During July 1953 C. R. Parencia of the U. S. Department of Agriculture collected some lepidopterous larvae on cotton in Austin, Robertson, and Wharton counties in Texas which appeared to him to differ from the various kinds of larvae previously known to feed upon cotton. Early in July 1954 the same kind of larvae were found on cotton in Burleson and Matagorda counties, and by the middle of the month economic damage (defoliation) to several thousand acres of cotton was reported. Larvae collected in all these counties were referred, for determination, to my colleague, H. W. Capps. They were determined merely as "species of Acontiinae," since identified larvae of the species were not present in the United States National Museum. Eventually adults reared from larvae obtained in Brazos County, Texas, were submitted to me and identified as *Acontia dacia* Druce. Mr. Capps confirmed that the associated larvae were the same as those previously submitted. The common name "brown cotton leafworm" has been given to them.

This species is now known to occur also in Louisiana, a single specimen having been taken in a light trap at Natchitoches by L. D. Newsom on August 19, 1954, and 41 specimens on October 12, 1954. By October 20 Burns and Newson reported larval infestations from Natchitoches and Red River parishes. If *dacia* continues to be a pest of cotton and continues to appear in new areas, the ability to recognize the adults and the larvae of this species will be of value to cotton growers and entomologists. Martin & Mistric (1954) have described both stages. Their description of the larva is sufficient to separate this species from the larvae of the other species of Lepidoptera now known to feed on cotton, but their description of the adult is not adequate for the separation of *dacia* from many of the other acontiines occurring in this country. The purpose of this paper is to indicate the distinguishing characteristics of *dacia* and to point out that another species of nearly identical appearance, *Acontia terminimaculata* (Grote), also occurs in the United States and probably in some of the cotton-growing sections.

*Acontia dacia* is not new to Texas, there being several specimens in the collections of the United States National Museum from that State, including one from Brownsville collected in 1895. The species also occurs in Mexico and in Guatemala. To my knowledge, however, *dacia* was not previously known from those areas in which it suddenly appeared as a pest, although very likely it had occurred there for several years. This assumption is based on the report of Martin & Mistric (1954) that population buildups and damage occurred in fields being regularly treated with most of the chlorinated hydrocarbon insecticides recommended for the control of cotton insects. If resistance was developed elsewhere and if the occurrence in an apparently new area represents only an extension of range, then we should have had reports of this species occurring on cotton in those areas from which the species was previously known. As yet there have been no such reports. On the other hand, the data from Louisiana indicate that there has been at least some extension of range.

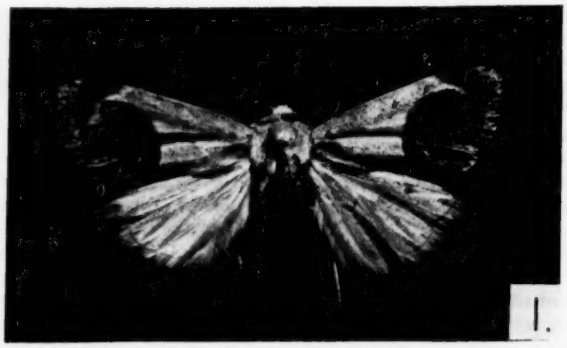
*Acontia terminimaculata* appears to be restricted to the eastern United States, but material available for study is too limited for an accurate determination of its distribution. This species is most abundantly represented in collections by specimens from New York and Florida. Very few specimens from other States have been available. In the United States National Museum there are single specimens from Decatur, Illinois; "Georgia"; and "New Jersey." Forbes (1954) states that *terminimaculata* (as *Tarache terminimaculata* Grote) occurs from Massachusetts to Florida, Illinois, and Louisiana. He lists *Tilia* as the food plant of *terminimaculata*. If *dacia* has a food plant other than cotton, it probably is some wild malvaceous plant, and it should be sought in those areas from which *dacia* was previously known to occur, especially the eastern coastal areas of Guatemala and Mexico.

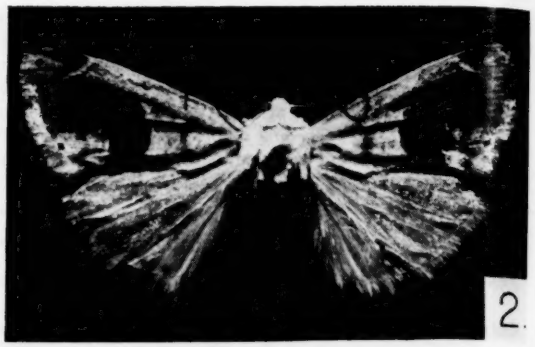
Males of *dacia* (Fig. 1) and *terminimaculata* (Fig. 2) may be separated from males of the other species of *Acontia* occurring in this country by the following characteristics: The grayish coloration of the basal portion of the forewing extends along the costa to a point about one-fourth the length of the forewing from the apex. At that point a very oblique, white line, extending from the costa toward the outer margin of the wing, meets an evenly curved, white, transverse line which separates the dark and light areas of the wing. *The angle formed by the junction of these two white lines is very acute* and is characteristic of *dacia* and of *terminimaculata*. Males of these two species also have a transparent fovea at the base of the forewing in the cell formed by the anal veins (2nd A and 3rd A). In the latter character they agree with the species of the *lactipennis-tetragona* complex, but differ from all the other species of *Acontia* in this country. In the females (Figs. 3 and 4) the angle formed by the white lines of the forewing is not always as distinct as in the males, but *a dark, transverse, basal bar* of the forewing may be used to distinguish these species from the other species of *Acontia* occurring in this country. This basal bar may also be found in some males of both species, but it is not nearly so dark or so distinctly marked as in the females.

At the present time the ranges of *dacia* and *terminimaculata* are not known to overlap, except possibly in Louisiana. However, if *dacia* becomes established in other cotton-growing areas of the Gulf States, it might become necessary for the field entomologist to separate the adults of the two species. The variation of the wing pattern is such that no constant differences have been discovered. *A. terminimaculata* is usually larger than *dacia*, but this difference is one of degree and consequently of little value. The genitalia, however, provide excellent characters for the separation of these two species. In the male genitalia the right valve of *terminimaculata* is much broader than the left valve, whereas in *dacia* the two valves are of about the same width. In addition, the costal processes of both valves are quite different (Figs. 5 and 8). The female genitalia are generally similar, but the sclerotized process at the ostial opening is produced farther to the right in *dacia* than in *terminimaculata*, and *dacia* has a small triangular plate in the ductus bursae near the opening into the bursa, which is lacking in *terminimaculata* (Figs. 6 and 7).

[1] Accepted for publication April 15, 1955.

[2] Lepidoptera: Phalaenidae.



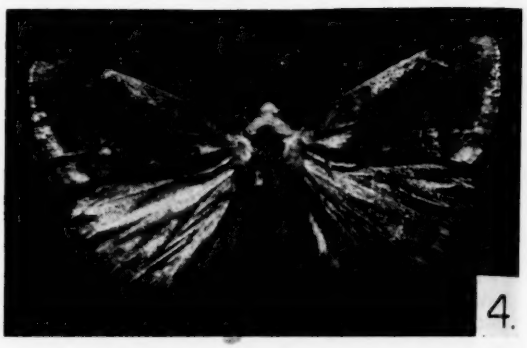



PLATE I

EXPLANATION OF PLATES

PLATE I. Adults, dorsal view.

FIG. 1.—*Acontia dacia*, male.
FIG. 2.—*A. terminimaculata*, male.
FIG. 3.—*A. dacia*, female.
FIG. 4.—*A. terminimaculata*, female.

PLATE II. Male and female genitalia.

FIG. 5.—*Acontia terminimaculata*, male, aedeagus removed, ventral view.
FIG. 5a.—*A. terminimaculata*, male, lateral view of aedeagus.
FIG. 6.—*A. dacia*, female, ventral view
FIG. 7.—*A. terminimaculata*, female, ventral view.
FIG. 8.—*A. dacia*, male, aedeagus removed, ventral view. Aedeagus not shown as it is nearly identical to that of *terminimaculata*.

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## The Distribution and Nomenclature of the Corn Earworm[1, 2]

E. L. TODD, *Entomology Research Branch, Agr. Res. Serv., U.S.D.A.*

In a recent study Common (1953) has shown that the name *Heliothis armigera* (Hübner) is applicable to an Old World species and that the corn earworm of the Americas and several species in Australia, especially *Heliothis punctigera* Wallengren, have been confused with *armigera*. *H. armigera*, which was described from European specimens, also occurs in suitable areas throughout Africa, and in Asia (Turkestan, India, China, Japan, Indochina and the Malay Peninsula), Indonesia, Australia (coastal and subcoastal Queensland and New South Wales), New Zealand, Fiji Islands, Philippine Islands, and Guam. The species that we know as the corn earworm (also listed as the bollworm and tomato fruitworm in "Common Names of Insects Approved by the American Association of Economic Entomologists," Jour. Econ. Ent., 43: 117–138, 1950) occurs throughout much of the New World. Its range extends from a latitude of 52° N. (Saskatoon, Saskatchewan) to at least 35° S. (Montevideo, Uruguay). It also occurs on the Hawaiian Islands, apparently having been introduced from North America.

Forbes (1954) also treated the American corn earworm as distinct from *armigera* of the Old World. He used the specific name *obsoleta* Fabricius, recognizing that it is invalid (*Bombyx obsoleta* Fabricius, Entomologia Systematica, vol. 3, pt. 1, p. 456, 1793, is a primary homonym of *Bombyx obsoleta* Fabricius, Systema Entomologiae, p. 579, 1775, an Australian lymantriid), but pro-

[1] Accepted for publication April 15, 1955.
[2] Lepidoptera-Phalaenidae.

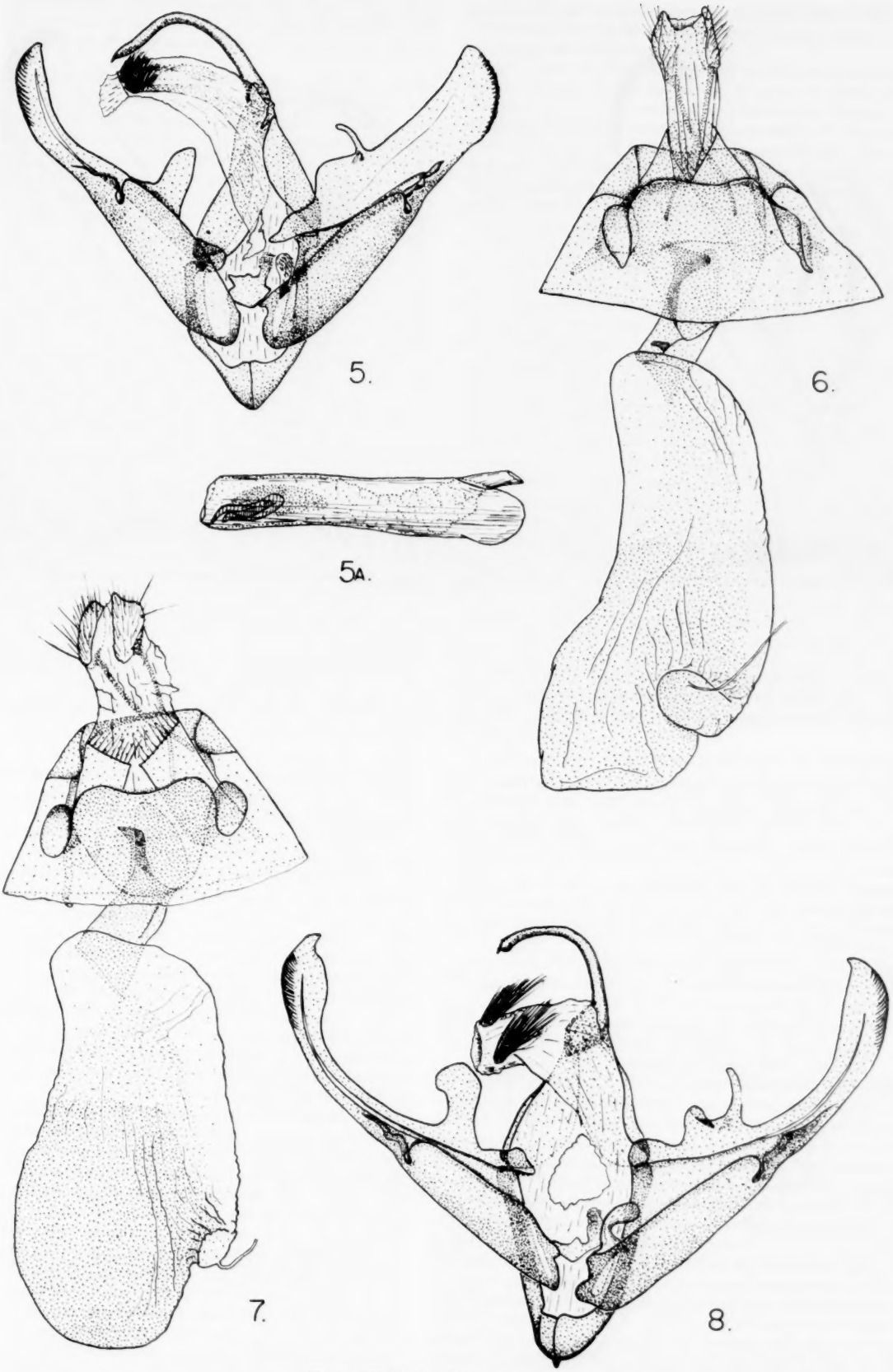
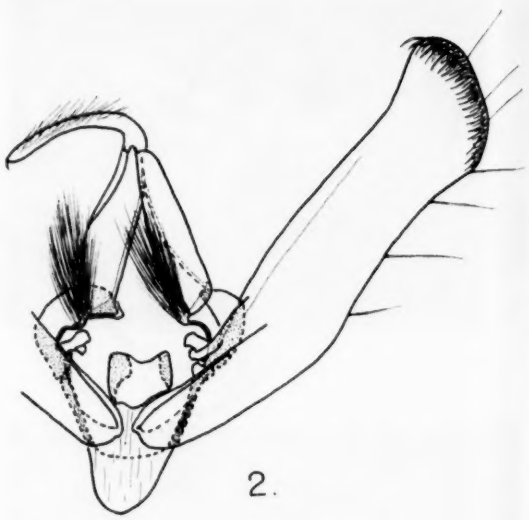



PLATE II. Explanation on opposite page.

FIG. 1.—*Heliothis gelotopoeon* (Dyar)—Portion of male genitalia, ventral aspect, aedeagus removed.
FIG. 1a.—*H. gelotopoeon* (Dyar)—Aedeagus, lateral aspect.



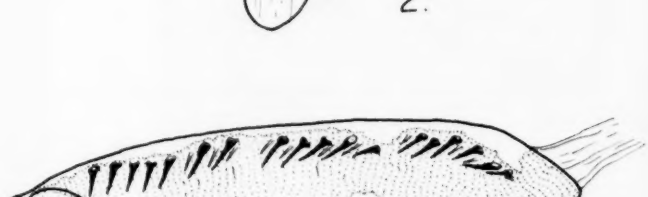




FIG. 2.—*Heliothis zea* (Boddie)—Portion of male genitalia, ventral aspect, aedeagus removed.
FIG. 2a.—*H. zea* (Boddie)—Aedeagus, lateral aspect.

posing that it be a *nomen conservandum*. Common (1953) suggests that *Heliothis umbrosus* Grote (Ent. Soc. Philadelphia Proc. 1: 219, 1863) should probably be the name applied to the American species. However, there is an older available name, *Heliothis zea* (Boddie). Boddie described the adult and immature stages of this species as *Phalaena zea* in the Southern Cultivator for September 1850 (vol. 8, no. 9, p. 132). The article also appeared in whole or in part (adult description) in the following publications:

a) Farmer and Planter, vol. 1, no. 10, p. 157, Dec. 1850.
b) Cotton Planter's Manual (J. A. Turner, editor), pp. 157–160, C. M. Saton and Co., New York, 1857.
c) Fourth Report of U. S. Entomological Commission, U. S. Department of Agriculture (Riley, editor), Note 60, pp. 120, 121, 1885 (adult description).

Apparently the article was also reprinted in the Southern Sentinel, a Columbus, Georgia, newspaper, sometime after its appearance in the Southern Cultivator, and before it was reprinted in the Farmer and Planter. I have not been able to obtain that newspaper, and therefore cannot give an exact citation. Riley's citation (4th Rpt. U. S. Ent. Comm., pp. 358, 382) of "American Cotton Planter, July 1850" as the source of the original description of *Phalaena zea* Boddie is erroneous. The first volume of the American Cotton Planter did not appear until 1853, and a thorough search of the early volumes failed to reveal that the article ever appeared as a reprint in that journal.

Besides describing the various stages, Boddie also made detailed observations on the biology of *zea*, which show beyond any doubt that the species he was treating was the corn earworm. He recognized that the corn earworm and the cotton bollworm were the larvae of the same species. He also offered some suggestions as to control (to reduce damage to cotton) in the original paper and in a supplementary paper which appeared in the Southern Cultivator, in November 1850.

The conclusion of Chiarelli de Gahan & Touron (1954) that *zea* (as *armigera*) and "*Thyreion*" *gelotopoeon* Dyar (Insecutor Inscitiae Menstruus, vol. 9, p. 60, 1921) represent a single species appears to be erroneous in view of the consistent differences in the genitalia of the males. The type series of *gelotopoeon* are from Tucumán and La Rioja, Argentina. Other specimens from the following localities have been examined. Brazil: Pelotas, RIO GRANDE DO SUL. Uruguay: Montevideo, MONTEVIDEO. Paraguay: Villarrica, GUAIRÁ; "Paraguay." Peru: "Peru." Argentiaa: Tucumán, TUCUMÁN. Chile: El Canelo, SANTIAGO; Guayacán, SANTIAGO. These data indicate that *gelotopoeon* has a relatively restricted distribution, but more material and further study will be required before the range can be satisfactorily defined.

The two species may be differentiated on the basis of several morphological characteristics. The valves of the male genitalia are of different shape—broad and of nearly uniform width for the apical two-thirds of their length in *zea;* narrow for most of their length, with the apical portion of the costa considerably produced in *gelotopoeon*. Other differences exist in the aedeagi. The aedeagus of *gelotopoeon* has a heavily sclerotized "thorn" (a term applied by Common to a homologous structure in *armigera*) on the vesica just within the distal orifice. This "thorn" is not present on the aedeagus of *zea*. Also the cornuti are smaller and more numerous in *gelotopoeon*, and the aedeagus is usually shorter than the valve, whereas in *zea* it is usually longer than the valve. The presence of the "thorn" and the size of the aedeagus indicate that *gelotopoeon* is more closely related

to *armigera* and other Old World species. Conversely, the cornuti resemble those of *zea* more closely than those of *armigera*. The male genitalia of *gelotopoeon* and *zea* are illustrated in figures 1 and 2.

An apparent difference in the spinulation of the tibia of the foreleg undoubtedly prompted Dyar to describe *gelotopoeon* and to place the species in the genus *Thyreion* Smith. However, the structure of the head and the male genitalia indicate that this species should be placed in *Heliothis* Ochs. The work of Chiarelli de Gahan & Touron (loc. cit.) raises a question as to the value, as a specific character, of the number of spines present on the outer margin of the foretibia. An examination of the material before me revealed that this character alone is not always sufficient to separate the two species. In *zea* the spinulation of the outer margin (posterior margin when the leg is at a right angle to the longitudinal axis of the body) of the foretibia is relatively constant. In a study of more than 200 specimens (16 from South America) only 2 (both from Canada) were found to have more than a single apical spine on the outer margin of the foretibia. Each of these two specimens has an additional spine near the middle of the outer margin of the foretibia. This spine is small and almost completely concealed by the scales. On the other hand, the number of spines on the outer margin of the foretibia of specimens of *gelotopoeon* is extremely variable. Most of the specimens have a row of 4 to 6 well-developed spines, but others not so many, some of them only a single apical spine as in most specimens of *zea*. It appears, therefore, that specimens with three or more spines on the outer margin of the foretibia may be safely identified as *gelotopoeon*. Other means will be required to separate specimens that have less than three spines in this position and which are from the area in which both species are known to occur. A study of the male genitalia will permit the identification of the two species, but I know of no reliable character that will enable one to separate the females. I have been unable to find distinguishing characteristics in the female genitalia. The markings of the underside of the wings may be useful, but they are not always reliable. In *gelotopoeon* there is usually a distinct black discal mark at the end of the cell of the hind wing and a black basal dash below the orbicular of the forewing. However, these markings may be obscure in *gelotopoeon* and they are occasionally found in specimens of *zea*.

I wish to thank all those who have aided in the preparation of this paper, especially George H. Goodwin, librarian, Division of Insects Library, U. S. National Museum, for locating the source of the original description of *Heliothis zea* (Boddie) and the various reprints of that description.

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## Use of Synergized Pyrethrins to Prevent Oviposition by Cattle Grubs[1]

EARLE S. RAUN, *Iowa State College, Ames*

Possibly the most desirable method of controlling larvae of cattle grubs, *Hypoderma lineatum* (De Vill.) and *H. bovis* (L.), would be to prevent oviposition by the adult flies. In this way, worry caused by the attacking flies and damage caused by the infesting grubs would be averted.

In an effort to effect this type of control automatic treadle sprayers similar to the equipment designed by Bruce (1952) were used on two Angus cow and calf herds near Creston, Iowa, in late spring and summer of 1953. The treadle unit was installed in the entrance to a salting corral in one pasture. The other herd used a unit installed in the entrance to the watering area. The material used in the treadle sprayers was Pyrenone T-143, containing 10% piperonyl butoxide and 1% pyrethrins.

In pastures adjoining those of the treated herds were untreated herds of the same blood lines. These untreated herds were used as check animals. At weekly intervals during June, July, and August, the test herds were observed as to the effectiveness of the sprayers and the material against the various species of biting flies. This gave an indication as to whether the machines were working properly.

Since cattle exposed to grub attack apparently become less susceptible to infestation from year to year, observations of the effectiveness of treatments were limited to calves born in the spring of 1953. Thus, in December of 1953, 15 calves from each of the 2 treated herds and 15 calves from the 2 untreated herds were selected at random. These calves were marked with numbers and grub counts were made at the time. Grub counts were again made during January, February, March, and April. At each examination period grubs were extracted from each calf in order to determine the percentage of the two species of warbles present at any one examination.

The use of the automatic treadle sprayers applying Pyrenone T-143 did not give the same results in the two herds of Angus cattle when winter grub counts were taken. In the one herd there was no difference in the numbers of grubs becoming encysted in the backs of the treated and untreated cattle. In the other herd, however, the counts showed an over-all reduction in grub numbers of 47.4 per cent in the treated animals as compared with the untreated animals. The difference in grub counts was statistically significant.

The degree of control in the latter herd was not striking until the data were broken down by months and compared with the numbers and percentages of the two grub species present in the backs of the cattle at each observation period (Table 1). In those months during which *Hypoderma lineatum* was present, grub control was excellent. As the numbers of *H. bovis* increased, however, the degree of control began to drop. When only *H. bovis* was present, there was no significant difference in the numbers of grubs in the treated and untreated portions of the herd.

**Table 1.—Grub control by the summer use of activated pyrethrins, and species collected at monthly intervals. Creston, Iowa, 1953–54.**

| | December | January | February | March | April | Average |
|---|---|---|---|---|---|---|
| Per cent control | 100.0 | 86.5[b] | 62.3[b] | 43.4[a] | 22.9 | 47.4[b] |
| Distribution of Species | | | | | | |
| Per cent *Hypoderma bovis* | 0.0 | 0.0 | 16.2 | 83.3 | 100.0 | |
| Per cent *H. lineatum* | 100.0 | 100.0 | 83.8 | 16.7 | 0.0 | |

[a] Significant at 5% level.
[b] Significant at 1% level.

There appears to be a logical explanation as to why *H. lineatum* was controlled in one herd and *H. bovis* was not. This explanation lies in the oviposition habits of the females of these

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two species. While *H. lineatum* is known to spend a period of time with a standing or prone animal, depositing a number of eggs on a single hair, *H. bovis* deposits eggs singly as animals are active or even running madly to escape attack. Apparently these differences in habits would permit the *H. lineatum* females being affected by the repellent qualities of the insecticides on the animals, while *H. bovis* would not be repelled due to the shortness of time the fly is near the treated animal.

There also appears to be a simple explanation as to why similar or comparable results were not achieved with the herd where the treadle sprayer unit was located in the entrance to the salt corral in the pasture. The mineral requirements for calves are met during the first 3 or 4 months of their lives by the minerals contained in the milk of the dams. Milk contains approximately 0.2% sodium chloride, which would be sufficient for spring-born calves for the greater part of the summer pasture season. The calves used in the grub counts were not older than 60 days at the beginning of the heel fly season and were not observed to go, and undoubtedly did not go, through the unit to any extent to get salt during the early part of the summer when *Hypoderma lineatum* females were ovipositing. On the other hand, the calves of the other test herd were known to have used the sprayer since they were observed to go to water with their mothers, even early in the summer.

SUMMARY.—The use of a synergized pyrethrin concentrate containing 10 per cent piperonyl butoxide and 1 per cent pyrethrins effectively prevented oviposition by the females of the common cattle grub, *Hypoderma lineatum*, when the material was applied daily to the legs, flanks, and backs of cattle by an automatic treadle micro-sprayer. However, this treatment did not prevent oviposition by the northern cattle grub, *Hypoderma bovis*, under conditions of the test.

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## Weight Gains in Feeder Calves Treated with Low Pressure Rotenone Sprays to Control Cattle Grubs[1]

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Experimental tests were carried out during the winters of 1951 and 1952, near Rolfe, Iowa, in an effort to shed light on the question "Are there increased rates of weight gain in feeder calves following the use of rotenone-bearing grub control sprays?"

Feeder calves were placed in two groups of approximately equal weight and grub count. This was done by pairing animals according to weight and grub count 30 days after first grub appearance in the loin area, and placing one of each pair in one or the other of the experimental groups at random. In 1951 there were 22 animals in the tests and in 1952 there were 30. The calves averaged between 450 and 500 pounds at the start of the tests each year. Each month during the time that encysetd grubs were present, weights and grub counts were recorded for each animal. The animals were under test each year for 3 months.

On days when weights were scheduled to be taken, water and feed were withheld in order to eliminate variations in the amount of "fill" that might otherwise affect the individuals' weights.

The sprays used were made up of 7.5 pounds of 5% rotenone, with 2 pounds of Dreft as a wetting agent, in 100 gallons of warm water. They were applied with a John Bean orchard-type hand gun with a solid cone spray pattern and at a pressure of 100 pounds developed by a gasoline engine operated piston pump. Rotenone applications were made three times at monthly intervals beginning with the first observation day each year. All animals were housed, fed, and watered together. Also, all animals were treated with a spray containing 0.175% lindane, in order to eliminate any variable which might be interjected into the test results by weight losses due to lice or mange.

During the test period, both *Hypoderma lineatum* (De Vill.) and *H. bovis* (L.) were present in the experimental calves. In 1951 the highest average grub count for any one month was 19, while in 1952 the highest average was 53 per animal. During both years, grubs were controlled very well; the average kill in 1951 was 76.8 per cent and in 1952 it was 89 per cent.

The treatment of the calves with rotenone sprays did not result in significant increases in rates of gain, however (Table 1). In 1951, the treated animals gained an average of 4.7 pounds more than the untreated animals during the 90-day test period. In 1952, the rates of gain were a little better, 11.6 pounds in favor of the treatment, but still when analyzed statistically, the differences were not significant.

**Table 1.—Weights of calves treated and untreated for cattle grub control, Rolfe, Iowa.**

| WEIGHT GAINS IN POUNDS | | | |
|---|---|---|---|
| 1951 | | 1952 | |
| Treated | Untreated | Treated | Untreated |
| 155 | 110 | 60 | 55 |
| 115 | 115 | 60 | 65 |
| 105 | 135 | 95 | 100 |
| 110 | 95 | 45 | 50 |
| 105 | 85 | 115 | 85 |
| 125 | 105 | 90 | 80 |
| 115 | 125 | 40 | 125 |
| 95 | 85 | 85 | 40 |
| 115 | 115 | 80 | 65 |
| 85 | | 55 | 35 |
| | | 90 | 10 |
| Avg. 112.5 | 107.8 | 50 | 45 |
| | | 55 | 85 |
| | | 65 | 80 |
| | | 60 | 50 |
| | | Avg. 69.6 | 58.0 |

It should be pointed out that this study does not throw any light on whether or not the *prevention* of grub infestation in cattle will produce increased rates of gain in weight or in milk production. It seems probable that the grubs would do more damage during the 6 to 9 months they are migrating through the animal's bodies than during the 1 to 2 months they are encysted in the loin area.

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## Effect of Bayer 17147 on Boll Weevil[1]

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Experiments were conducted in 1954 on the effect of Bayer 17147 (a benzo triazine derivative of a dithio phosphoric acid methyl ester) on boll weevil, *Anthonomous grandis*. Boh. The primary objectives of the study were to determine the toxicity,

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**Table 1.—Speed of action of Bayer 17147 and toxaphene dusts against the boll weevil.[a]**

| Treatment | Pounds per Acre | Hours Exposure and Per Cent Mortality | | | | | |
|---|---|---|---|---|---|---|---|
| | | 4 Hours | | 24 Hours | | 72 Hours | |
| | | Per Cent | Angle | Per Cent | Angle | Per Cent | Angle |
| Check | — | 0 | 0.00 | 2 | 3.69 | 2 | 3.69 |
| Toxaphene, 20% | 10 | 0 | 0.00 | 12 | 13.16 | 50 | 44.95 |
| Toxaphene, 20% | 20 | 0 | 0.00 | 22 | 24.82 | 64 | 53.82 |
| Bayer 17147 5% | 10 | 76 | 66.56 | 100 | 90.00 | 100 | 90.00 |
| Bayer 17147, 5% | 20 | 100 | 90.00 | 100 | 90.00 | 100 | 90.00 |
| L.S.D. at 5% level | | — | 13.53 | — | 16.47 | — | 8.16 |
| L.S.D. at 1% level | | — | 18.64 | — | 22.70 | — | 11.24 |

[a] The boll weevils were exposed to leaves of cotton taken from field-dusted plots and placed in petri dishes in the laboratory.

speed of action, and residual effectiveness of Bayer 17147 to boll weevil.

PROCEDURE.—Dusts of 5 per cent Bayer 17147 and 20 per cent toxaphene were applied to cotton plants in the field at the rates of 10 and 20 pounds per acre. A weighed amount of each dust was applied with a plunger type hand-duster to a 1/80-acre plot, consisting of 4 rows 38.9 feet long. Each plot was covered lightly three times with the dust in order to give even distribution of the insecticide on all plants. Leaves were removed from plants selected at random on each plot immediately after the application of insecticides and each 24 hours thereafter for 12 days. The sixth leaf from the terminal bud was selected as representative and used throughout the experiment. Five leaves were selected from the two inside rows of each treated and untreated area each day. These leaves were taken to the laboratory, and each leaf was placed in a petri dish. Ten boll weevils, collected from the field on the date used, were placed on each of the leaves. Mortality counts were made 4, 24, 48, 72, and 96 hours after the insects were exposed to the insecticides.

RESULTS.—Mortality data on the speed of action of Bayer 17147 and toxaphene applied in the field and exposed to the boll weevil in the laboratory are shown in table 1. Bayer 17147 was much faster in its toxic action than toxaphene. When insects were exposed to cotton leaves immediately after treatment at the rates of 10 and 20 pounds per acre, the Bayer compound killed 76 and 100 per cent of the weevils, respectively, in 4 hours.

Mortality records of boll weevils exposed in the laboratory to insecticides weathered in the field are presented in table 2. The residual effectiveness of 5 per cent Bayer 17147 was longer than that of 20 per cent toxaphene. After weathering 10 days, Bayer 17147 still caused 100 per cent mortality to weevils exposed to leaves treated at the rate of 10 pounds per acre. By the 12th day, the mortality dropped to 84 per cent. The kill from toxaphene was lower at all intervals and rates of application.

SUMMARY.—Experiments were conducted to determine the effect of Bayer 17147 on adults of the boll weevil, *Anthonomous grandis* Boh. Five per cent Bayer 17147 and 20 per cent toxaphene were applied to foliage of cotton in the field as dusts at the rates of 10 and 20 pounds per acre. Insects were exposed in petri dishes to leaves taken from each plot immediately and at 24-hour intervals for 12 days after application. The initial kill was more rapid and residues which resulted in mortality persisted longer on plants treated with Bayer 17147 than on plants treated with toxaphene.

## Malathion to Control the Northern Fowl Mite[1]

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The northern fowl mite, *Bdellonyssus sylviarum* (C. and F.), is known to be one of the most serious pests of poultry in the temperate region. The mites feed on the host both day and night, and can live away from the host for as long as 3 weeks. Vincent *et al.* (1954) obtained effective control by applying 4% malathion dust to chickens with a puff duster. In addition, 4% malathion dust applied as a litter treatment at the rate of 1 pound to 20 square feet showed considerable promise.

In early February, 1955 a large poultry breeding farm in Maryland reported a serious northern fowl mite infestation in their breeding flock of 2,000 White Leghorn chickens. Since malathion had previously shown considerable promise in controlling this pest, the owner consented to the testing of 4% malathion dust with emphasis being placed on litter treatments.

PROCEDURE.—Ten pens each containing approximately 125 hens and 6 roosters were included in the tests. Before the treatments were made 10 hens and 4 roosters in each pen were caught, banded, and the degree of infestation on each bird given a numerical value as reported by Vincent *et al.* (1954): 0=no mites observed; 1=one to several mites, no greying of feathers; 2=numerous mites with greying of feathers; and 3=many mites with blackened feathers and scaly skin. Mean mite infestations on the banded hens and roosters in each pen were determined. The infestations were located primarily in the vent region. In general, roosters were more heavily infested than hens.

In pens 1 and 2, litter treatments were applied by hand at the rate of 1 pound to 20 square feet. In pens 3 and 4, litter treatments were applied by hand at the rate of ½ pound to 20 square feet. In pens 5 and 6, litter treatments were applied by hand at the rate of ¼ pound to 20 square feet. The litter condition in pens 1, 2, 3, and 4 was good (dry and fluffy), the owner having put down new sugar cane litter prior to the treatments. In pens

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**Table 2.—Mortality of boll weevil adults exposed in the laboratory to insecticides weathered in the field.**

| Treatment | Pounds per Acre | Days Weathering and Per Cent Mortality | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2 Days | | 4 Days | | 6 Days | | 8 Days | | 10 Days | | 12 Days | |
| | | Per Cent | Angle | Per Cent | Angle | Per Cent | Angle | Per Cent | Angle | Per Cent | Angle | Per Cent | Angle |
| Check | — | 4 | 7.38 | 10 | 14.02 | 18 | 24.22 | 10 | 14.02 | 10 | 14.31 | 12 | 13.16 |
| 20% Toxaphene | 10 | 92 | 79.38 | 88 | 74.06 | 74 | 60.29 | 42 | 40.33 | 10 | 16.38 | 12 | 18.00 |
| 20% Toxaphene | 20 | 94 | 81.00 | 94 | 81.00 | 86 | 73.03 | 36 | 36.13 | 16 | 23.31 | 18 | 24.56 |
| 5% Bayer 17147 | 10 | 100 | 90.00 | 100 | 90.00 | 100 | 90.00 | 100 | 90.00 | 100 | 90.00 | 84 | 77.31 |
| 5% Bayer 17147 | 20 | 100 | 90.00 | 100 | 90.00 | 100 | 90.00 | 100 | 90.00 | 100 | 90.00 | 100 | 90.00 |
| L.S.D. at 5% level | | | 13.67 | | 13.46 | | 13.54 | | 11.72 | | 28.59 | | 20.71 |
| L.S.D. at 1% level | | | 18.83 | | 18.55 | | 18.65 | | 16.15 | | 39.39 | | 28.53 |

5 and 6, the litter was not changed and was quite damp when the treatments were made. All litter treatments included mixing a small handful in the nesting material of each nest. In pens 7 and 8, the chickens were confined in a corner of the pen and the dust was sprinkled over them, using about 4 pounds to a pen. In pens 9 and 10, roosters only were picked up and individually dusted by hand about the vent and beneath the wings.

RESULTS.—To determine the results of the various treatments the banded hens and roosters were caught and the mean mite infestations determined. Roosters were considered separately from hens due to their reluctance to play in the litter and enter nests.

Table 1 gives the results of the litter treatments against hens and roosters. On hens the ½ pound and 1 pound rates were quite effective in killing the mites in from 1 to 4 days. In pens 5 and 6 where the litter was damp, the treatments at the rate of ¼ pound to 20 square feet were relatively ineffective against the mites. On roosters the treatments were as a whole ineffective in killing the mites.

In pens 7 and 8 where the chickens were dusted collectively, examinations showed the hens to be free of mites; however, most of the roosters were still infested. In pens 9 and 10 where the roosters only were picked up and dusted individually by hand, no live mites could be found in 24 hours after the treatments. Hens, however, were still infested.

Five days after the treatments were made the litter became wet due to a heavy snow. The owner in his anxiety to rid his farm from all mites put down new litter, applied 4% malathion dust litter treatments at the rate of ¾ pound to 20 square feet and dusted all the roosters individually. A 10-day check on the results of this overall treatment revealed all hens and roosters to be 100 per cent free from mites.

SUMMARY.—Litter treatments of 4% malathion dust applied to dry fluffy litter at the rates of 1 pound and ½ pound to 20 square feet and a little mixed into each nest were effective in controlling the northern fowl mite on hens. Good control was obtained within 1 to 4 days.

Heavy infestations on roosters were controlled effectively only by individual dusting with 4% malathion dust.

**Table 1.—Litter treatments with 4% malathion dust against the northern fowl mite on White Leghorn chickens.[a]**

| Pen | Rate of Application[b] | Litter Condition | Mean Mite Infestation: Before Treatment | After Treatment (Days): 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|---|---|
| | | | *Hens* | | | | |
| 1 | 1 | Dry | 2.1 | — | 0.0 | — | 0.0 |
| 2 | 1 | Dry | 1.6 | 0.0 | — | 0.0 | — |
| 3 | 0.5 | Dry | 1.4 | — | 0.0 | — | 0.0 |
| 4 | 0.5 | Dry | 2.8 | 1.4 | — | 0.7 | — |
| 5 | 0.25 | Damp | 2.5 | — | 2.2 | — | 2.0 |
| 6 | 0.25 | Damp | 2.3 | — | 2.0 | — | 1.8 |
| | | | *Roosters* | | | | |
| 1 | 1 | Dry | 3.0 | — | 3.0 | — | 3.0 |
| 2 | 1 | Dry | 3.0 | 2.7 | — | 2.7 | — |
| 3 | 0.5 | Dry | 2.0 | — | 0.0 | — | 0.0 |
| 4 | 0.5 | Dry | 2.5 | 2.5 | — | 2.5 | — |
| 5 | 0.25 | Damp | 3.0 | — | 3.0 | — | 3.0 |
| 6 | 0.25 | Damp | 2.5 | — | 2.5 | — | 2.5 |

[a] Records made from 10 hens and 4 roosters in each pen.
[b] In pounds to 20 square feet.

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## DDT Residues in Fat from Steers Pastured on Corn Stover in DDT-Treated Fields[1]

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It is a common practice of farmers in the Corn Belt to range feeder cattle in corn fields after harvest. The cattle pick up corn ears missed in harvesting and also feed on the stover. They are kept in the fields until the supply of food is exhausted, and are then moved to feed lots. Spraying corn with DDT for control of the European corn borer, *Pyrausta nubilalis* (Hbn.), leaves appreciable quantities of DDT on the plants. Fahey *et al.* (1953) have shown that when corn plants are treated with DDT for control of first-generation borers residues of 1 to 5 p.p.m. may be present at ear harvest.

It has been well established that DDT accumulates in the fatty tissues of animals that are fed DDT-contaminated food. Thomas *et al.* (1951) found that, after calves had been fed dry matter containing 2.2 to 106 p.p.m. of DDT for 160–230 days, the storage of DDT in the body and kidney fat ranged from 2.0 to 345 p.p.m., and that the DDT concentration in the fat was proportional to the intake. Radeleff, *et al.* (1952) learned that yearling Herefords fed 10 p.p.m. of DDT in all items of their feed for 30 days showed 6.8 p.p.m. in the fat on the last day of the feeding, and also that yearling steers with 11.2 p.p.m. in their fat immediately after being sprayed with DDT had only 2.9 p.p.m. in their fat 22 weeks later.

A study was made to determine whether or not feeder cattle ranging in corn stover treated with DDT for control of the European corn borer at the usual time and dosage would build up a measurable quantity of DDT in fat tissue and, if so, how long the DDT would persist after the animal was returned to a DDT-free diet.

TREATMENT OF CORN.—Two fields of corn were used, one of which received no treatment and the other received DDT sprays on June 25 and July 2. The sprays consisted of 1.5 pounds of technical DDT in an emulsifiable formulation diluted with water to 10 gallons for each acre. Samples for analysis of DDT residues in corn plants were collected on July 2, August 10, and September 23. Each sample consisted of ten 10-plant subsamples chosen at random. On October 14 a sample of stover (ten 1-square-yard subsamples chosen at random) was also collected for residue analysis. Each subsample was chopped in a small silage mill and well mixed, and a 1-quart (approximately 1 pound) aliquot was taken for analysis. The samples were analyzed for DDT by the Stiff-Castillo method (Fahey & Rusk 1951). Residue figures were calculated on green (undried) weights, and hence are not strictly comparable owing to the variations in water content.

The analyses showed that immediately after the second spray application (July 2) the corn contained 116.7 p.p.m. of DDT. Weathering and plant growth reduced this residue to 14.4 p.p.m. on August 10 and to 11.2 p.p.m. of DDT on September 23. The stover sample collected on October 14 contained 23.3 p.p.m. of DDT. The increase in DDT content between September 23 and October 14 is attributed to a decrease in moisture content of the plants between these dates. Similar corn and stover samples from the untreated corn field contained no DDT.

TREATMENT OF ANIMALS.—Five Hereford steers, each weighing from 786 to 884 pounds, were used in this experiment. A biopsy sample of loin fat was collected on October 12 to determine if the animals were free of DDT contamination. On Oc-

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[2] Also Iowa Agricultural Experiment Station.

tober 19 three of the animals were placed in the DDT-treated field and two animals in the untreated field. Additional biopsy fat samples were collected from each animal on November 20, December 21, February 6, and March 22. On December 21 the animals were removed from the fields, placed in a feed lot, and fed a DDT-free diet.

Biopsy samples were collected in the following manner: Steers were placed in a chute provided with a stanchion as the only means of immobilization. An area about 4 inches from the top of the withers over the posterior portion of the shoulder blade was shaved, and an incision about 4 inches long was made through the skin, exposing the fatty tissue covering the muscles. Tension was applied with a pair of artery forceps and the fat from the muscle dissected out with a sharp scalpel. In some of the steers it was impossible to remove fat without also removing some muscle tissue. The opening in the skin was closed with plain catgut sutures, and no attempt was made to remove the sutures as it would have meant extra handling of the steers.

The biopsy samples were cut into small pieces, mixed with approximately twice their weight of sodium sulfate (anhydrous), and then pureed with chloroform in a Waring Blendor. The solids were removed by filtration, and the chloroform extract was washed with sulfuric and fuming sulfuric acids to remove the fat. The chloroform solution of residue was then neutralized with sodium bicarbonate, the chloroform removed by evaporation, and the residue analyzed by the Schechter-Haller technique (Fahey & Rusk 1951).

All the animals were free of DDT contamination at the beginning of the experiment. Those kept on untreated stover did not show a measurable quantity of DDT at any time. On the other hand, the animals allowed to range on the DDT-treated stover showed from 1.0 to 2.8 p.p.m. of DDT after the first month, and this residue increased to about 5 p.p.m. by December 21, when the animals were moved to the feed lot. The DDT residue in the fat then diminished rapidly, and by March 22 only 0.1 p.p.m. or less could be found in biopsy samples.

On April 2 two of the animals (one from each field) were slaughtered, and fat samples from the omentum, kidney, and loin were collected. Ten-gram fat samples were handled in the same manner as the biopsy samples. When the sample was increased to 50 grams, the sulfuric acid extraction did not remove all the fat extractives. After the chloroform was removed, the sample was taken up in 10 ml. of pentane and transferred to a pentane wet column of Florosil and eluted with 150 ml. of pentane. The pentane solvent was removed by evaporation and the residue analyzed by the Schechter-Haller method.

Analyses of 10-gram samples indicated that some of them might contain as much as 0.1 p.p.m. of DDT. To make certain of this analysis, the size of the sample was increased to 50 grams. With the larger samples no DDT could be found in the fat of these animals. The animal from the treated field did contain a small quantity, less than 0.1 p.p.m. of DDT degradation products.

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## Dormant vs. Summer Control of the Grape Mealybug in the Yakima Valley[1]

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A summer spray of 1 lb. 25% parathion per 100 gal. was recommended by Frick (1952) only as an emergency measure for the control of the grape mealybug, *Pseudococcus maritimus* (Ehrh.), in the Yakima Valley, since it had been observed that some infestations virtually disappeared in 1 year due to the activity of natural enemies. In one vineyard, cocoons of a predatory brown lace wing, *Sympherobius* sp.,[3] were very numerous. Of 54 egg nests examined in the dormant season, four contained mealybug crawlers and 29 had one or more sympherobiid cocoons near them and were without crawlers. Eleven of 39 sympherobiid cocoons produced adults of *Dibrachys daphne* Gir.[3] (Pteromalidae, Hymenoptera). No lace wing adults emerged from any of the cocoons. *Chrysopa* sp. and several species of ladybird beetles were seen in the vineyards, but their importance was not determined. However, the persistence of infestations of mealybugs in many unsprayed vineyards suggested that a more practicable program be developed.

Vine growth is usually so heavy by late July that sprays can only be applied by hand guns from hoses dragged down the rows. Summer sprays, to be properly timed, are delayed until some honeydew appears. This means that a certain amount of sooty mold is present at harvest. Several of the processors have objected to the mold on the berries. Summer sprays cause the loss of much of the "bloom," which is undesirable for table grapes (Stafford & Kido 1955). This loss is of no importance on grapes to be processed. About 99 per cent of the grape acreage in eastern Washington produces grapes for processing, either for juice or wine.

Jensen *et al.* (1954) showed that ½ pound actual of emulsifiable parathion per 100 gallons gave good control when applied at a moderate pressure (350 p.s.i.) at about 600 gallons per acre as a dormant treatment. When a heavily infested vineyard was brought to our attention in March, 1954, it was decided to compare a delayed dormant spray against the recommended summer treatment.

METHODS.—The vineyard chosen has the rows 9 feet apart with the vines 8 feet apart in the rows. It was divided into four paired replications, each replication being 10 rows wide and about 30 vines long. The center row of each 5-row treatment was used for making counts, thereby giving four buffer rows between each count row. A delayed dormant treatment was applied on April 19 with a high pressure spray machine at about 350 p.s.i., using 25 feet of hose and a hand gun with a #6 orifice. About 1 gallon was applied per vine, half from either side. A 4-pound per gallon emulsifiable parathion[4] was used at 1 pint per 100 gallons. The entire vine was sprayed and the trunk and main leaders were drenched.

A summer spray of 1 lb. 25% parathion wettable powder per 100 gallons was applied August 10 and 11. A pressure of 600 p.s.i. was indicated at the machine, but 200 feet of hose were used. The gun had a #10 orifice and was adjusted to give a broad cone of fine mist. The vines were sprayed from both sides by dragging the hose down the rows. An average of ½ gallon per vine was used to obtain a coverage of all foliage, fruit, trunk, and leaders. Complete coverage was essential because many mealybugs were still under the bark of 1- and 2-year old wood,

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[2] Assistant Entomologist and Senior Experimental Aide, respectively.

[3] Determined by B. D. Burks, Insect Identification and Parasite Introduction Section, Entomology Research Branch, Agr. Res. Serv. U.S.D.A.

[4] *Orthophos 4*, 42% (4 lb./gal.) emulsifiable parathion, California Spray-Chemical Corporation.

**Table 1.—Parathion applied in different seasons against the grape mealybug.[a] Zillah, Washington, 1954.**

| Time of Application | Parathion Applied per 100 Gal.[c] | First Generation | Second Generation[b] | | |
|---|---|---|---|---|---|
| | | June 8 | Aug. 10 (Pre-spray) | Sept. 14 | Sept. 28 (pre-harvest) |
| Delayed Dormant (April 19) | 1 pt. (4 lb./gal.) | 4 | 6 | 4.5 (2)[d] | 1.5 (0.25) |
| Summer (Aug. 10–11) | 1 lb. (wettable powder, 25%) | 541 | 68 | 4.5 (2) | 0.0 (3.75) |

[a] June 8—number of mealybugs seen during 40 one-minute stops per treatment; August 10 and September 14—200 bunches counted each date; September 28—400 bunches counted.

[b] Per cent bunches contaminated with honeydew.

[c] Applied an average of 1 gallon per vine on April 19 and an average of ½ gallon per vine on August 10–11.

[d] Figures in parentheses give percentages of bunches with dry, sooty mold.

although enough were exposed on the fruits to produce a high percentage of bunches with honeydew on them.

RESULTS.—The results of the two spray applications are given in table 1. A heavy infestation had developed in the unsprayed blocks on June 8 and August 10. The summer spray, applied after most of the bunches had some honeydew on them, gave as good control as the delayed dormant treatment. Many dead mealybugs were seen on the bunches 9 and 10 days following the summer treatment. There was more sooty mold, *Capnodium* sp., on the fruit from the summer sprays as this spray was applied after 68 per cent of the bunches had some honeydew on them. An earlier application, when the first honeydew was deposited, probably would have reduced the amount of sooty mold at harvest.

SUMMARY AND CONCLUSIONS.—Either a delayed dormant spray of ½ lb. actual parathion per 100 gal. or a summer spray of ¼ lb. actual parathion per 100 gallons gave satisfactory control of grape mealybug, *Pseudococcus maritimus* (Ehrh.) in the Yakima Valley. However, more sooty mold, *Capnodium* sp., may result from the summer spray if this spray is delayed until most of the bunches have honeydew on them. In vineyards with a known infestation the delayed dormant application is preferred, but a summer treatment, applied as the first honeydew is deposited on the fruit, is satisfactory for vineyards needing preharvest control.

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## Races of Hessian Fly[1]

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Eight States growing winter wheat now include breeding for resistance to the hessian fly, *Phytophaga destructor* (Say), in their crop-improvement programs. It is therefore important to have a thorough understanding of the potentiality of hessian fly populations and the genetic factors controlling the ability of races of this fly to infest and develop on different winter-wheat varieties. To obtain such knowledge it is essential to study hessian fly races that now occur in the field or that may develop following the release of fly-resistant varieties.

A review of literature and field observations have indicated differences in the ability of hessian fly populations to attack identical wheat varieties located in different geographical areas. Painter (1930) mentions a difference in the ability of certain fly populations to infest specific wheat varieties grown in different sections of Kansas. Less than 2 per cent of the populations at Manhattan, Kans., were able to survive on the varieties Illini Chief sel. and Dawson, whereas the populations at Columbus, Kans., were able to infest 35 to 38 per cent of these varieties. At both locations the infestation of Kanred, a wheat susceptible to both populations, ran 35 to 60 per cent. In breeding experiments Painter found it possible to select a number of progenies that were able to infest Kanred but not Illini Chief and a few progenies with the ability to infest both these varieties.

Cartwright & Noble (1947) substantiated the existence of a strain of hessian fly in California that was different from the strain existing in Indiana. Indiana flies were able to infest the wheat varieties Dawson and Wabash, both of which were resistant to California flies.

Suneson & Hall (1953) reported hessian fly infestations of Mariout Barley in San Diego County, Calif., as indicative of a biotype distinct from those found at Lafayette, Ind., and Beltsville, Md. This is more evidence that hessian flies differ in their ability to infest the same host at different localities.

Three hessian fly races, each of which is able to infest certain wheats differing in their genes controlling hessian fly resistance, have now been developed at Lafayette. Ind. In these studies a race has been designated as a group of flies differing from another group in its ability to develop on specific wheat varieties representative of a definite inherited type of resistance. So far as can be determined, no morphological differences occur between the adults of these three races. Each race has been selected out of a locally reared population and inbred for six or more generations on a wheat variety representative of a specific type of resistance to the majority of native hessian flies. Over 3000 individual matings have been made thus far.

The wheat varieties used in these studies represent specific types of inherited resistance which differ from one another in the genes controlling their resistance to specific races of fly. It is assumed that other varieties, not used in these experiments but having the same gene components for resistance as the variety used, will react in the same manner to hessian fly.

Vigo, Michigan Amber, and CI 12557 are varieties having no resistance to any of the races of fly in these studies. CI 12985, a derivative of the W38 variety, is a fly-resistant soft red winter wheat developed at Purdue University Agricultural Experiment Station. It carries the W38 resistance to native flies, which is controlled by a single gene pair (Caldwell *et al.* 1946). A39153A1-11-1-1, a derivative of the durum PI 94587, is also a fly-resistant soft red winter wheat developed at Purdue. It has been suggested that the resistance of PI 94587 is controlled by more than one gene (Caldwell *et al.* 1946).

Race A is made up of hessian flies capable of developing on the wheat varieties Michigan Amber, Vigo, and CI 12557, but not on CI 12985 and A39153A1-11-1-1. This race of fly has been inbred for 14 generations.

Race B is composed of hessian flies capable of infesting the wheat varieties susceptible to race A, and also wheat CI 12985. Flies from race B cannot develop on the variety A39153A1-11-1-1, which has the PI 94587 resistance. Race B has been inbred for six generations.

Race C comprises hessian flies capable of infesting the wheat varieties susceptible to race A and also the wheat variety A39153A1-11-1-1. Hessian flies homozygous for race C's ability

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to infest A39153A1-11-1-1 are not capable of developing on CI 12985 having the W38 resistance. Race C has been inbred for six generations.

At present $F_1$ hybrids from single matings among races A, B, and C are being tested for their ability to infest the wheat varieties used above. Results so far are inconclusive, but they suggest that the ability of race B to develop on CI 12985 and of race C on A39153A-11-1-1 are recessive or hypostatic to the inability of race A to develop on the same varieties. A limited number of interracial crosses between homozygous individuals from races A and B and between homozygous individuals from races A and C resulted in very little or no infestation of CI 12985 by the progenies of the A×B hybrids and very little or no infestation of A39153A1-11-1-1 by the A×C progenies.

Also a limited number of interracial crosses between homozygous individuals of races B and C produced $F^1$ progenies, most of which were incapable of developing on A39153A1-11-1-1 but many were capable of developing upon CI 12985. All B×C progenies were able to develop on the wheat varieties susceptible to race A.

Extensive studies are now being carried on to determine if new races can be developed, to what extent hessian fly hybrids will develop on wheat varieties having particular types of resistance, the number of genes controlling the ability of each race to infest all representative wheat varieties, and the composition of various regional hessian fly populations.

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## The Biology of Tabanids in the Yazoo-Mississippi Delta[1, 2]

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Because of the importance of tabanids as livestock pests in the Yazoo-Mississippi Delta, studies on the biology of these flies were undertaken at Stoneville, Miss., in April 1953 in cooperation with the Delta Branch of the Mississippi Agricultural Experiment Station.

The Yazoo-Mississippi Delta is a part of the flood plains of the Mississippi and Yazoo Rivers. Approximately 200 miles long by 75 miles wide, it comprises 4.2 million acres in the northwestern part of Mississippi. The area has a mild climate, high humidity, and an average annual rainfall of approximately 50 inches. Extensive natural breeding places for tabanids are afforded by many crescent-shaped lakes which occur as remnants of former water courses, and by large numbers of bayous and low, swampy areas. These are supplemented by the rice fields of the area, and by innumerable borrow pits flanking the long stretch of levee along the Mississippi River.

Tabanids are a pest of livestock over most of the year in the Delta. Adults were collected from March 29 to November 6 in 1953 and 1954. Most of the 30 species collected were in the genus *Tabanus*. Deer flies were scarce; only one species, *Chrysops flavida* Wied, was observed on livestock. The species observed to be of economic importance were: *Leucotabanus annulatus* (Say), *Tabanus americanus* Forst., *T. atratus* F., *T. cymatophorus* O. S., *T. equalis* Hine, *T. fulvulus* Wied., *T. fuscicostatus* Hine, *T. lineola* F., *T. mularis* Stone, *T. proximus* Walk., *T. sulcifrons* Macq., and *T. turbidus* Wied. Stockmen report severe outbreaks of tabanids in previous years, but adult populations during this study were below these reported levels.

*Tabanus lineola* and closely related species were the dominant horse flies in the Delta during the last two seasons. Larvae of this complex apparently are highly adaptable. They are commonly found along the shores of lakes, in mud around the edges of borrow pits and bayous, and in the banks of irrigation ditches. In swamps they have been found under the bark and in the punky wood of floating logs, or in accumulations of dirt or moss on similar logs, and in the debris around the bases of bald cypress trees. In rice fields they have been found in terraces and in the thick, greenish scum that accumulates on the water. In dry situations half-grown or larger larvae have been collected under cow dung or partially buried objects as far as 150 feet from standing water.

*Leucotabanus annulatus* larvae have been collected from both willow and elm tree holes and from rotting logs. When the common willow in the area is cut down, sprouts grow from the stump, and some may become trees. When this occurs, the cambium layer of the stump survives but the heart usually decays, which results in a cavity. Larvae ranging in numbers from 5 to 60, have been found in several of these cavities. Empty pupal cases have also been observed in the surface material of these cavities. Larvae have been taken from elm tree holes whose openings were from 5 to 22 feet above the ground. The larvae in these holes ranged in numbers from 3 in one small cavity to 73 in a large cavity. In both willows and elms these larvae tend to be in the nonpulverized material next to the sound, moist wood, and can be easily overlooked, expecially if the hole is rather dry. Larvae of two distinct sizes were found in most of the holes, which suggests a two-year life cycle. Most examinations of elms were made in recently felled trees, but even so a thorough examination of most holes is difficult without a saw.

The larval habitats of *Tabanus atratus* include almost any fairly permanent body of water which is slow-moving or stagnant. During May 1953 large larvae were abundant along the banks of Cottonwood Lake, between the levee and the Greenville Bridge across the Mississippi River. An average of two and as many as four larvae of this cannibalistic species were found per square foot of soil along the banks of the lake. Throughout the summer of 1954, *atratus* larvae of various sizes were abundant in the Delta area. The adult population in both 1953 and 1954 did not reach the levels anticipated after the larval surveys.

Although no serious outbreak of *Chlorotabanus crepuscularis* has been observed in the Delta, numerous larvae have been found in borrow pits along the Mississippi River. The larvae live at the water line in accumulations of trash and growths of greenish algae and moss. Large numbers also inhabit loose organic material that gathers along the edge of the water in wooded areas.

Biological studies through 1954 have failed to reveal the larval habitats of the remaining economic species in the Delta area.

During May, in both 1953 and 1954, torrential rains inundated all but the highest ground in most of the area. Drainage facilities were overtaxed, and floodwaters receded slowly. Observations made in 1954 revealed that multitudes of tabanid larvae were flushed from their normal habitats by the high water. These larvae were found under the bark of floating logs, in punky

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[2] In cooperation with the Delta Branch of the Mississippi Agricultural Experiment Station, Stoneville.

wood, or clinging to leaves, tree trunks, sticks, and other objects at the water's surface. Many were swept away by the currents, while others were left stranded in unsuitable habitats. In a five-day period of intermittent collecting more than 200 larvae were taken from the shallow water along one 150-foot stretch of flooded bayou. Some of these larvae were in eddies, or lodged trash, but others were being carried along by the current. Several days after the water receded no larvae could be found in the mud at the bayou's edge. These floods were probably the major factor in reducing the number of adults during these two seasons.

## Relative Toxicity of Six Insecticides to Two Strains of the House Fly[1]

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A wild strain of the house fly, *Musca domestica* L., collected at Auburn, Alabama, by Oliver & Eden (1955) was shown to be 14 times as resistant to DDT as a susceptible (Orlando) strain obtained from the U.S.D.A. Entomology Research Branch Laboratory, Orlando, Florida. Oliver & Eden (1955) showed that there was no statistically significant difference between the resistance of two strains of the house fly to two other chlorinated hydrocarbons, lindane and endrin. Other workers have shown that when a strain of flies has developed resistance to DDT, it may also have resistance to other chlorinated hydrocarbon insecticides. Wilson & Gahan (1948) determined the resistance of an Orlando-resistant strain to several insecticides other than DDT, which was the insecticide used in the selection of the strain. The DDT-resistant strain was also more resistant to chlordane than was the regular colony. A strain of flies resistant to DDT, chlordane, toxaphene, lindane, methoxychlor, and pyrethrins was developed by Pratt & Babers (1950) by exposing an Orlando-Beltsville resistant strain to mixtures of those insecticides. Bruce (1950) studied the susceptibility or resistance of various strains of the house fly by topical application of the toxicant to the thorax of the female. He found that a strain of flies that was resistant to DDT also had resistance to toxaphene and chlordane. Experiments were conducted at Auburn, Alabama, during the summer and fall of 1954 to determine the extent of resistance of native wild flies to six insecticides.

PROCEDURE.—The same two strains of flies used by Oliver & Eden (1955) in previous experiments were used in these studies. The native flies were designated as the Auburn strain and the non-resistant strain obtained from the U.S.D.A. at Orlando, Florida, was designated as the Orlando strain.

Flies were reared by a modification of the Harrison (1949) method and maintained in an artificially lighted laboratory with the temperature controlled at 27 to 30° Centigrade. The culture was fed a 1:1 mixture of evaporated milk and water.

The toxicants were applied to the venter of adult flies in 2 microliter droplets by a micrometer syringe device proposed by Trevan (1922). The technical materials were dissolved in acetone and applied after the flies had been anesthetized with carbon dioxide in a funnel device described by Williams (1946). A series of five dosage levels was used for each compound. Four replications of 25 three- to five-day old flies were used at each dosage level. Treated flies were provided with food and water daily. Mortality counts were made 24 hours after application of the toxicants. The percentages of mortality were adjusted by Abbott's (1925) formula and plotted on dosage-mortality curves, from which the LD-50's were read. The flies used in the experiments were weighed and the LD-50's were expressed in micrograms of insecticide per gram of fly as well as micrograms per fly.

The LD-50's to both strains of flies were determined for methoxychlor, chlordane, heptachlor, chlorthion, Diazinon, and isochlorthion.

RESULTS.—The LD-50's of the six insecticides are presented in table 1. The most toxic insecticide to the Auburn strain of flies was Am. Cyanamid 4124, with an LD-50 of 0.03 micrograms per fly. This was significantly more toxic than Diazinon, which had an LD-50 of 0.06 micrograms per fly. Diazinon was more toxic than chlorthion. There was a distinct break between the phosphorus compounds and the chlorinated hydrocarbons. Methoxychlor was the most toxic of the three chlorinated hydrocarbons, with an LD-50 of 2.33 micrograms per fly. Heptachlor and chlordane were much less toxic.

The LD-50's to the Auburn strain of flies were approximately the same as those for the Orlando strain. The only instance in which there was significant difference between the LD-50's of the two strains of flies was Diazinon, which was more toxic to the Auburn strain than to the Orlando strain. The LD-50's were in approximately the same proportion, whether expressed as micrograms per fly or micrograms per gram of fly.

Based on these data, it would appear that wild strains of flies that have developed resistance to DDT do not necessarily have resistance to other chlorinated hydrocarbons or organic phosphates.

SUMMARY.—The LD-50's of six insecticides to two strains of the house fly, *Musca domestica* L., were determined by topical applications of the insecticides in acetone solutions. One strain of flies (Auburn) was 14 times more resistant to DDT than the

[1] The data herein are taken from a thesis presented by the senior author to the Alabama Polytechnic Institute in partial fulfillment of the requirements for the M.S. degree. Accepted for publication April 25 1955

Table 1.—L.D.-50's of six insecticides to two strains of the house fly.

| INSECTICIDE | LD-50 | | | |
|---|---|---|---|---|
| | Auburn Strain | | Orlando Strain | |
| | Micrograms per: | | Micrograms per: | |
| | Fly[a] | Gram of Fly | Fly[a] | Gram of Fly |
| Chlordane | 12.00–29.00–57.00 | 2791.30 | 14.00–42.00–84.00 | 3586.80 |
| Heptachlor | 11.00–13.00–17.00 | 855.79 | 8.75–11.00–15.00 | 955.68 |
| Methoxychlor | 2.03– 2.33– 2.53 | 135.18 | 1.33– 1.93– 2.33 | 127.49 |
| Chlorthion | 0.10– 0.14– 0.20 | 10.52 | 0.19– 0.21– 0.25 | 16.89 |
| Diazinon | 0.05– 0.06– 0.07 | 3.01 | 0.09– 0.10– 0.11 | 6.15 |
| Am. Cyanamid 4124 | 0.03– 0.03– 0.03 | 2.75 | 0.02– 0.02– 0.03 | 1.73 |

[a] The middle figure is the L.D.-50; others indicate the 0.95 fiducial limits. Figures are rounded off at two decimal places.

other (Orlando). The LD-50's of the insecticides to the Auburn and Orlando strains, respectively, in micrograms of insecticide per fly were as follows: Am. Cyanamid 4124, 0.03 and 0.02; Diazinon, 0.06 and 0.10; chlorthion, 0.14 and 0.21; methoxychlor, 2.33 and 1.93; heptachlor, 13.00 and 11.00; and chlordane, 29.00 and 42.00. With the exception of Diazinon, there was no significant difference between the LD-50's of the two strains. Diazinon was significantly more toxic to the Auburn strain.

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## *Diatraea grandiosella* Dyar as a Host of *Chelonus annulipes* Wesm.[1]


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Parasitization of the European corn borer, *Pyrausta nubilalis* (Hbn.), by the braconid *Chelonus annulipes* Wesm, was discovered by H. L. Parker in 1925 while working in Italy (Vance 1932). Bradley (1941) reports that he reared *annulipes* on *Ephestia kuehniella* Zell. and that K. A. Bartlett reared it on *Diatraea saccharalis* (F.) and *Corcyra cephalonica* Staint. in Puerto Rico.

Details of the biology, morphology, and ecological isolation of *annulipes* in Europe were published by Vance (1932). Various phases of the parasite's physiology were given by Wishart & Van Steenburgh (1934) and Bradley & Arbuthnot (1938). Baker *et al.* (1949) presented data on importations from Italy into the United States and indicated that this parasite now has a restricted distribution in North America.

During the summer of 1954 a study was undertaken at Stillwater, Okla., to determine whether or not *annulipes* could be reared on the southwestern corn borer, *Diatraea grandiosella* Dyar. The parasites came from domestic collections of the European corn borer and were shipped from Moorestown, N. J., to Oklahoma by S. W. Carter.

HANDLING OF ADULT PARASITES AND HOST EGGS.—Approximately 240 adult parasites, taken from the shipment, were confined in a wooden-framed screen-wire cage, 12 by 12 by 16 inches, in a laboratory room where the temperature ranged from 80° to 102° F. Wet absorbent cotton and dry sugar cubes were kept in the cage to provide water and food. The cage was blanketed with wet cotton batting to raise the humidity and to provide darkness, a condition that Bradley (1941) found prolonged the life of *annulipes*.

*Diatreae grandiosella* egg masses on small pieces of plant tissue were collected from dent corn in the middle of July. They were difficult to find in the field at that time, because the peak of second-brood oviposition had passed. The eggs varied in maturity. Some were freshly laid while others were several days old and showed advanced embryonic development. They were stored in pint-sized cardboard food cartons with moist paper toweling to prevent desiccation.

PARASITE OVIPOSITION.—The first attempt to induce *annulipes* females to oviposit in *grandiosella* eggs was made on July 17. When it was found that females taken at random seldom oviposited, individuals that alighted and searched over pieces of green corn stalk placed in the cage were selected for oviposition. Attempts at obtaining oviposition were made at various times throughout the day but were successful only between 8 and 10 A.M. Vance (1932) showed that females were more likely to oviposit if isolated in small enclosures. Therefore, the isolation cages used in these tests were 1-inch glass tubes 12 inches long with the ends stoppered with moist absorbent cotton.

A female parasite was placed in an isolation cage with a small piece of corn plant tissue bearing a *grandiosella* egg mass. The parasite was watched constantly until she had apparently oviposited in the eggs. In this manner 11 egg masses containing a total of 29 eggs were attacked by the parasites on July 17 and 5 more egg masses containing 16 eggs on July 19.

HOST REARING.—The 16 egg masses in which the parasite apparently oviposited were transferred to corn plants averaging 18 inches in height in a greenhouse where daily temperatures ranged from approximately 80° to 110° F. One egg mass was placed in the whorl of each of 16 plants. The growing leaves, unfurling from the whorl, caused some egg masses to dislodge, and each morning some were found on the ground and returned to the plant whorls. The recovery of only 11 borers from the plants indicates that many of the eggs were lost, desiccated while in contact with the ground, or injured while being replaced on plants. Some mortality may have occurred among the very young larvae during their establishment on the plants. (Later experimental work on infesting greenhouse corn with *grandiosella* showed that few eggs were dislodged if they were placed inside the leaf sheaths below the plant whorls.)

RECOVERY OF HOST BORERS.—Vance (1932) indicated that the length of larval life of *annulipes* inside the host *nubilalis* was approximately 19 days at a constant temperature of 77° F. The borers were therefore dissected from the corn plants on August 2, 16 days after the initial placement of egg masses on the plants, to avoid possible issuance of parasites from hosts within the plants. Eleven *grandiosella* larvae were recovered and isolated in ½- by 2-inch glass shell vials and fed sections of green corn stalk.

PARASITE ISSUANCE, PUPATION, AND EMERGENCE.—The 11 borers recovered included 8 that appeared to be stunted. Two parasite larvae issued from stunted borers on August 4 and attempted to spin cocoons, but failed and soon died. Two parasite larvae issued from stunted borers on August 5, spun normal cocoons, and pupated, and on August 13 and 14 normal males emerged. One parasite larva issued from a stunted borer on August 7, spun a normal cocoon, and pupated, but the adult failed to emerge. Three stunted borers died on August 5, and dissection showed third instars of *annulipes* in two of them.

One of the three normal borers pupated on August 7, and the other two died on August 11 and 15.

DISCUSSION.—Vance (1932) states that European corn borer larvae parasitized by *annulipes* are much smaller and lighter in color than normal larvae of the same instar. He also reports that, prior to issuance from the fourth-instar larvae, the parasite larvae spin light cocoons as if preparing for pupation, and within the cocoons they appear rather plump, lie quietly, and have much the appearance of prepupae. *D. grandiosella* larvae parasi-


[1] Accepted for publication April 29, 1955. This study was conducted in cooperation with the Department of Entomology, Oklahoma Agricultural Experiment Station.

tized by *annulipes* showed similar reactions. They were much smaller than normal larvae of the same instar, ceased feeding 24 to 48 hours prior to parasite issuance, retreated into their tunnels inside small pieces of corn stalk provided them as food, and spun brownish silken webs over openings in the tunnels. When disturbed in the tunnels, they appeared sluggish and showed little movement. Parasites issued from what appeared to be either fourth- or fifth-instar hosts. Actual issuance of parasites was not observed.

Parasites that pupated did so within 24 hours after issuance. The two parasite larvae that failed to pupate were subjected to abnormal conditions. They had fallen or crawled from the tunnels which their hosts had occupied and were crawling on the bottoms of the vials. Vance (1932) states that *annulipes* larvae disturbed in any way are unable to construct a cocoon—they must remain in the silken web of the host.

Behavior of the female parasites during oviposition in *grandiosella* eggs was very similar to that described by Vance (1932).

SUMMARY.—*Chelonus annulipes*, Wesm., an imported parasite of the European corn borer, *Pyrausta nubilalis* (Hbn.), successfully parasitized the southwestern corn borer, *Diatraea grandiosella* Dyar, in the laboratory. Of 11 host borers reared from eggs exposed to oviposition by the parasite, 8 were stunted. Parasite larvae issued from five of the stunted hosts. Three of them spun cocoons and pupated normally, and male adults of *annulipes* emerged from two of them. Three other stunted larvae died and dissection showed parasite larvae in two of them. Behavior of the adult parasites in the act of ovipositing and the effects of parasitization on this host were very similar to those described in the literature for the European corn borer.

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## *Aceria tulipae* (K.) Damaging Garlic in California

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The eriophyid mite, *Aceria tulipae* (Keifer), was named by Keifer (1938) from tulip (*Tulipa* sp.) bulbs collected in Sacramento, California, said to have originated in Holland. Keifer (1952) lists additional hosts as onion (*Allium cepa*) and garlic (*Allium sativum*) and gives its distribution as North America and Europe.

The role of *Aceria tulipae* in transmitting streak-mosaic of wheat was demonstrated by Slykhuis (1953). Painter & Schesser (1954) designated it as the wheat curl mite (common name approved by the Entomological Society of America in 1955), and

FIG. 1.—Damage to late garlic by *Aceria tulipae* (K.): left, damaged; right, normal.

record western wheat grass, *Agropygon smithii*, as an oversummering host and potential source of infestation of wheat.

The mite was called to the attention of the present writer by L. K. Mann on April 12, 1954, at Davis, Yolo County, California. Virus-like symptoms on garlic appeared at Davis for several years prior to 1954, and difficulty was experienced in trying to eliminate damage from garlic breeding stocks by means of selection. The mites were found in stored garlic bulbs where they concentrated particularly on the green growing tip and to some extent between the white bracts. Keifer (1952) mentions the drying on onion and garlic bulbs due to the feeding of this mite, and this was noticed in the Davis infestation. Infested bulbs were found to dehydrate and to break down due to secondary decay. Uninfested bulbs on the other hand remained firm and did not break down as rapidly in storage.

It appears that most of the damage caused by this mite is due to feeding during storage. The foliage shows virus-like damage; a stunting, twisting, curling, and yellow-mottling (Fig. 1). The mites move up into the protected folds of the leaves and continue feeding. The pattern of infestation in the field also indicates that the most important damage occurs in storage, and later spread to adjacent plants does not seem to cause extensive typical damage. In severe infestations *Acercia* causes a permanent disfigurement of the plants, but often there is a tendency, particularly in light attacks, to outgrow the damage. Field infestations on garlic have been found in the Hollister area, San Benito County, and at Gilroy and San Jose in Santa Clara County. Due to the widespread movement of planting stock it is probable

[1] The control studies reported were conducted in cooperation with Dr. L. K. Mann, Department of Vegetable Crops, University of California, Davis.

[2] Accepted for publication May 2, 1955.

that the mite is widely distributed in the garlic growing areas. Damage seems to be more severe in the late garlic varieties than early garlic.

*Aceria tulipae* was found in storage and in the field in association with *Rhizoglyphus callae* Oudm., and in storage with *Glycophagus domesticus* de Geer. (Determined by Dr. H. H. J. Nesbitt.)

In a test conducted during 1954, clean bulbs stored for 90 days with infested bulbs and held at 68° F. in heat sealed lumarith bags indicated a range in number of mites per bulb from 1 to 1,285 mites, with an average of 69 mites. A comparable lot stored under similar conditions, except that the bulbs were dusted with sulfur, gave a range from 0 to 1 mite per bulb, with an average of 0.03 mite. Methyl bromide fumigation using 2.5 pounds per 1,000 cu. ft., with a 2-hour exposure at 80° F., gave a complete reduction of mites with no damage to the bulbs. A combination of fumigation and dusting sulfur to prevent reinfestation, may prove practical. It is assumed that fumigation affected the eggs, or mites would have reappeared in the treated bulbs. Control by cleaning up the planting stock seems to be the most important control measure at the present time. In the field dusting of the foliage with sulfur, or the use of sulfur-DDT combinations as commonly used against onion thrips, should keep the mite under control. Mites are extremely difficult to reach once they are present in the protected folds of the leaves.

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## Insecticide Tests on the Squash Bug

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The squash bug, *Anasa tristis* (Deg.), has been one of the most difficult insects to control. Eichmann (1945) discussed the biology and economics of the insect in Washington and different methods of control. Pack (1930) and Moore (1936) suggested the use of calcium cyanide, but this method was never very satisfactory. Hoerner (1938) reported that a pyrethrum extract dust was effective, and Tate & Gates (1945) found that sabadilla gave good control. Walton (1946) found that sabadilla was more effective than either DDT or pyrethrin, but later (1947) that DDT, BHC, and chlordane gave longer periods of protection than did sabadilla. O'Kane (1947) reported that a BHC dust gave nearly complete control of the nymphs and considerable control of the adult bugs. Magee & Gaines (1950) found in cage tests that parathion and an analog of parathion were rather toxic to the nymphs and the adults.

While the writers were conducting some insecticide tests at Chillicothe, Ohio, in 1952 on the Mexican bean beetle, *Epilachna varivestis* Muls., they had an opportunity to test some of the new materials against the squash bug. Some laboratory tests and one field experiment were made.

LABORATORY TESTS.—The lower halves of 6-inch petri dishes were treated with insecticide dusts by a vacuum bell-jar method (Farrar *et al.* 1948), and then covered with pieces of cheesecloth fitted over embroidery hoops. Ten adult squash bugs were put in each dish and supplied with a piece of gourd for food. The dishes were held for 24 hours in a cabinet at about 75° F. that was lighted for about 9 hours by fluorescent lights, and then the numbers of dead and moribund insects were recorded. The tests were replicated on different days.

Dusts containing malathion at 5 per cent and dieldrin, aldrin, endrin, isodrin, NPD, and EPN at 2 per cent were compared in tests that were replicated five times. The mortality in 24 hours was 67 per cent with aldrin, 100 per cent with all the other insecticides, and 0 per cent in the untreated checks. The dust charge was 100 mg., which gave a deposit of less than 0.275 mg. per square centimeter. A second series was started in which the charge of dust was reduced to 50 mg., but only enough bugs could be collected to run two replicates. These results indicate that parathion, malathion, EPN, and dieldrin were the most effective materials.

FIELD EXPERIMENT.—These tests were made in a planting of gourds that was heavily infested with large nymph and adult squash bugs. The plants were growing in rows on string trellises and were marked off in single-row plots about 20 feet long and according to a randomized-block design for six treatments with four replications. The insecticides were applied with knapsack sprayers and dusters. After 24 hours counts were made of both living and dead bugs in a 5-foot section of the row in each plot.

The results of these tests are summarized in table 1. The number of bugs was considerably reduced by all the treatments. The numbers of dead bugs show that much of the reduction was due to kill. The results for A-42 indicate that the reduction in living bugs was due chiefly to repellency, since few dead bugs were found under the plants treated with this material. The large numbers of dead bugs found under the plants treated with parathion and malathion indicate that these materials should give considerable control of the insect.

**Table 1.—Effectiveness of different insecticides against the squash bug.**

| INSECTICIDE | AMOUNT PER ACRE | BUGS PER 5 FEET OF ROW | |
|---|---|---|---|
| | | Living | Dead |
| | *Pounds* | | |
| Dusts: | | | |
| Malathion 5% | 41 | 19.2 | 33.5 |
| A-42,[a] 2% | 48 | 20.8 | 2.7 |
| Parathion 2% | 52 | 4.0 | 27.5 |
| | *Gallons* | | |
| Sprays (2 lb. per 100 gal.): | | | |
| Aldrin | 100 | 4.8 | 19.0 |
| Chlordane | 100 | 8.0 | 18.2 |
| Untreated check | — | 40.8 | 1.8 |

[a] Arsenomethane As-As disulfide.

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## Laboratory Tests of the Effect of Insecticides on Some Beneficial Insects[1]

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The convergent lady beetle (*Hippodamia convergens* Guér.), the striped collops (*Collops vittatus* (Say)), and the spotted lady beetle (*Coleomegilla maculata* (Deg.)) occur rather generally on weeds and cultivated plants in the Phoenix area of Arizona and are often abundant on certain crops that are usually treated with insecticides. The striped collops may be found in large numbers on cantaloups infested with spider mites, and all three species of predators have been collected in large numbers from alfalfa fields that were heavily infested with the yellow clover aphid, *Myzocallis trifolii* (Monell). Since the abundance of these beneficial species may be seriously affected by insecticide treatments, some laboratory tests were made on the toxicity of some of the common insecticides to them.

Small sugar beets were plotted in No. 2 tin cans and dusted with different insecticides by a vacuum method similar to that described by Farrar *et al.* (1948). The plant and a weighed charge of dust in a small receptacle were placed under a bell jar, and the atmospheric pressure was reduced to 15 inches by a vacuum pump. Removal of a small stopper in the top of the bell jar allowed the air to rush into the jar and distribute the dust over the plant. The treated plants were immediately removed from the bell jar and covered with cloth-capped cylindrical cages made of cellulose acetate. Ten adult insects from the field were placed in each cage and held for about 24 hours at room temperature (about 75°–80° F.) and under fluorescent lights that were turned on between 8 A.M. and 5 P.M. At the end of this time both dead and moribund insects were counted and recorded as mortality. Dust charges of 50 mg. were used in the tests with the convergent and spotted lady beetles and 100 mg. in those with the striped collops. Replications of the tests were made on different days. There were 5 replications on the lady beetles and 10 on the striped collops.

**Table 1.—Percentages of mortality of some beneficial insects treated with insecticides.**

| Dust | Striped Collops | Convergent Lady Beetle | Spotted Lady Beetle |
|---|---|---|---|
| DDT 5% | 38 | 6 | 32 |
| Perthane 5% | 23 | 6 | 12 |
| Strobane 5% | 10 | 18 | 12 |
| Heptachlor 2.5% | 41 | 30 | 38 |
| Toxaphene 10% | 32 | 12 | 36 |
| Endrin 1% | 27 | 10 | 18 |
| Dieldrin 2% | 36 | 4 | 24 |
| Parathion 2% | 65 | 78 | 98 |
| Malathion 5% | 47 | 90 | 100 |
| Chlorthion 5% | 64 | 82 | 100 |
| Diazinon 4% | 37 | 66 | 100 |
| Untreated | 11 | 4 | 0 |
| L.S.D. at 5% level | 20 | 24 | 26 |

The results are summarized in table 1. The mortalities for the striped collops are generally lower than those for the lady beetles, although twice as much dust was used. The striped collops thus seems to be the most resistent of these species to insecticide deposits on the plants and may be less seriously affected than some beneficial insects by insecticide treatments. However, it may be more susceptible to insecticides ingested with its prey, since this possibility was not investigated. In the tests on this insect Perthane, Strobane, and endrin showed no significant effects as compared with the untreated check. The parathion and Chlorthion dusts were significantly more toxic than all the other materials except malathion. The data on the two lady beetles show that the phosphorus compounds, parathion, malathion, Chlorthion, and Diazinon, were significantly more toxic than any of the other materials.

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## Homopterous Insects Attacking Avocado in Central America and Mexico[1]

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During the period from November, 1953, through February, 1954, the junior author visited those areas of Central America and Mexico in which the avocado is indigenous. He was primarily interested in the discovery of mite predators on avocado and only incidentally collected insects attacking this tree. Some of the collections were from cultivated avocado, but most of them were from wild trees growing on their native hills.

SCALE INSECTS.—One Asterolecanine scale species, 2 mealybugs, 4 soft scales, and 11 armored scales are listed (Table 1) from avocado in these collections. Those species that have been fully identified are not restricted to avocado, but occur on many kinds of plants, some only in tropical America and some throughout the world. Enough collections were made to give a reasonably good sample of the scale insects on avocado in this part of its native home. None of the scale insects were found to be causing economic damage except the Florida red scale, *Chrysomphalus ficus* (Ashm.), which was injuring avocado in one location in Honduras, where it appeared to be a recently introduced species. Most, if not all, of the other species seemed to be under effective biological control. Ebeling (1950) lists only four of these species as attacking avocado.

WHITEFLIES.—Seven collections of aleyrodids as against 36 collections of scale insects indicate that the former were considerably less numerous than the scales. The 7 collections proved to include the following 7 species:

Aleurodicinae, prob. n. gen. near *Ceraleurodicus*, Honduras
Aleurodicinae, prob. n. gen. near *Dialeurodicus*, taken twice in Honduras
*Aleurodicus dugesii* (Ckll.), Mexico
*Bemisia* sp., possibly *inconspicua* (Q.), Guatemala
*Paraleyrodes* sp. near *goyabae* (Goeld.), Mexico
*Tetralicia* sp., Honduras
*Trialeurodes similis* Rsl., Mexico

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**Table 1.—Scale insects (Coccoidea) taken on avocado in Central America and Mexico.[a]**

| | HOND. | COSTA R. | NIC. | SAN SALV. | GUAT. | MEX. | TOTAL |
|---|---|---|---|---|---|---|---|
| COLLECTING STATIONS: | 11 | 3 | 1 | 1 | 12 | 8 | 36 |
| ASTEROLECANIIDAE | | | | | | | |
| *Cerococcus* sp. (new) | | | | | 1 | | 1 |
| PSEUDOCOCCIDAE | | | | | | | |
| *Dysmicoccus* sp. (new) | 1 | | | | | | 1 |
| *Farinococcus olivacus* (Ckll.) | | | | | | 1 | 1 |
| COCCIDAE | | | | | | | |
| *Ceroplastes floridensis* (Comst.) | 1 | | | | 1 | | 2 |
| *Coccus hesperidum* L. | 4 | 1 | 1 | 1 | 2 | 3 | 12 |
| *Coccus magniferae* (Green) | 2 | | | | | | 2 |
| *Toumeyella* sp. (new) | 1 | 1 | | | 1 | | 3 |
| DIASPIDAE | | | | | | | |
| *Acutaspis albopicta* (Ckll.) | 1 | | 1 | | 3 | 2 | 7 |
| *Aspidiotus destructor* Sign. | 1 | 1 | 1 | | 1 | | 4 |
| *Chrysomphalus dictyospermi* (Morg.) | 1 | 1 | | | 3 | 2 | 7 |
| *Chrysomphalus ficus* (Ashm.) | 1 | | | | | | 1 |
| *Diaspis* sp. near *miranda* (Ckll.) | 1 | 1 | | | 5 | 4 | 11 |
| *Hemiberlesia* sp. near *diffinis* (Newst.) | | | | | 6 | 1 | 7 |
| *Hemiberlesia lataniae* (Sign.) | | | | | 3 | 2 | 5 |
| *H. palmae* (Ckll.) | 3 | 2 | 1 | | 4 | 1 | 11 |
| *H. rapax* (Comst.) | | 1 | | | | 2 | 3 |
| *H. cyanophylli* (Sign.) | 1 | | | | 2 | 1 | 4 |
| *Selenaspidus articulatus* (Morg.) | | | | | 5 | | 5 |

[a] Number of collection stations and number of collections of each species are shown for each country.

Since these few small collections turned up such a scattering of species, it would appear that future collecting might be expected to produce many additional species of whiteflies. All the species taken were rare and therefore doing no damage to the trees. All whitefly identifications were by L. M. Russell. The avocado whitefly, *Trialeurodes floridensis* (Q.), was not taken.

*Leafhoppers.*—Some 14 species of leafhoppers were taken on avocado. Since most of these were adults it is probable that most of the specimens taken were casuals from other hosts. The exceptions were leafhoppers of the genus *Idona*, which were found in two locations in Mexico and one in Honduras in sufficient numbers to damage the leaves of a number of avocado trees. Leafhoppers taken were the following:

*Agalliopsis* sp., Guatemala
*Carneocephala dyeri* (Gibs.), Costa Rica
*Draeculacephala* sp., Honduras
*Erythrogonia laudata* (Fowl.), Honduras
*Homalodisca triqueta* (F.), Honduras
*Hortensia* sp., Costa Rica
*Idona* spp. (at least 2 spp.), Mexico and Honduras
*Oncometopia* sp., Honduras (2 collections)
*Scaphytopius* sp., Guatemala and Mexico
*Tettigella instrata* (Fowl.), Guatemala
*Tettigella miniaticeps* (Fowl.), Costa Rica
*Tylozygus fasciatus* (Walk.), Costa Rica
*Tylozygus* sp., Honduras

Leafhopper determinations were by D. A. Young.

TREEHOPPERS.—One species of membracid, the avocado treehopper, *Metcalfiella monogramma* (Germar), is sometimes a serious pest of avocados. Apparently restricted to avocado, its nymphs may mass so thickly on branches that parts or occasionally whole trees are killed. This species was taken in good numbers, particularly in Mexico. Other treehoppers taken were *Ceresa coccinea* Fowler in Costa Rica, *Membracis mexicana* Guerin in Guatemala, and *Stictolobus minor* Forbes and *Stictopelta indeterminata* (Walk.) in Honduras.

PSYLLIDS.—The avocado psyllid, *Trioza anceps* Tuthill, and possibly two closely related species cause leaf galls on avocado in this area. It is a very common insect and does some economic damage even though the avocado appears to be quite tolerant.

*Casidara dugesii* Leow. was taken on avocado in Honduras.

CERCOPIDS.—*Clastoptera* sp. and *Tomaspis postica* Walk. were taken on avocado in Costa Rica.

AETALONIDS.—*Aetalion* sp. was taken in Guatemala and *Aetalion quadratum* Walker in Mexico.

SUMMARY.—A survey of the homopterous insects on avocado in its original home in Central America and southern Mexico discovered 51 species. Insects found to be damaging avocado trees were the avocado treehopper, *Metcalfiella monogramma* (Germar), the avocado psyllid, *Trioza anceps* Tuthill, and an apparently undescribed leafhopper, *Idona* sp. Of the 18 species of scale insects taken, only the Florida red scale was doing harm, and where found in Honduras, it appeared to be a recently introduced insect.

ACKNOWLEDGMENT.—The authors express their appreciation to the many experts who have assisted in insect identification, especially to L. M. Russell, D. A. Young, and Harold Morrison, of the Insect Identification and Parasite Introduction Section, Entomology Research Branch, Agricultural Research Service, U. S. Department of Agriculture, Washington, D. C.; to Howard McKenzie of the California State Department of Agriculture, Bureau of Entomology, Sacramento; and to R. A. Flock of the University of California at Riverside.

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## The Toxicity of Certain Organic Insecticides to the Sweetpotato Weevil[1]

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During 1954 considerable interest arose relative to the possibility of controlling the sweetpotato weevil, *Cylas formicarius*

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[2] Now at North Carolina State College, Raleigh.

*elegantulus* (Sum.), with synthetic organic insecticides in seed beds and field plantings in Texas.

Investigators in Hawaii (Sherman 1951, Sherman & Mitchell 1953) have done considerable work on the chemical control of this weevil and other insects of the sweet potato under field conditions. Cockerham & Deen (1948) reported on the use of organic insecticides to control the sweetpotato weevil under field conditions, but little, if any, information regarding the toxicity of the relatively new organic insecticides to the sweetpotato weevil has been published. Laboratory tests were conducted at College Station, Texas, in 1954 to determine the toxicity of certain organic insecticides to this insect. Results of these experiments are reported herein.

MATERIALS AND METHODS.—Laboratory tests were conducted to determine the effectiveness of several chlorinated hydrocarbons and phosphorous compounds applied as dusts and sprays to control the sweetpotato weevil. All insecticides were applied as dusts or sprays at the rate of 0.5 pound active ingredient per acre. The sprays were made by diluting emulsifiable concentrates with water. The dusts were made by diluting dust concentrates with Attaclay. The treatment tower was 18 inches in diameter and 44 inches in height. The sprays were applied at the rate of 7.5 gallons per acre from the top of the tower through a solid cone nozzle at a pressure of 40 pounds p.s.i. The chlorinated hydrocarbon dusts, with the exception of endrin, were applied at the rate of 10 pounds per acre from the top of the tower by a sharp and constant air blast. Endrin dust was applied at 33 pounds per acre. The phosphorous compound dusts were applied at 20 pounds per acre.

The spray tests were conducted on five dates. Each treatment was replicated three times on each date. Untreated checks were used in each test. Survival records were made 48 hours after the insecticides were applied. Percentages of control were calculated by Abbott's formula. The dust tests were conducted in a similar manner, but not on the same dates as the spray tests. Insecticides were applied to shallow jelly glasses filled to within 0.5 inch of the top with damp soil in which cut sweet potato discs were partially submerged. Ten laboratory-reared adult sweetpotato weevils were released in each jelly glass 30 minutes after treatment, and the weevils were confined to the glasses by perforated metal lids. The tests were conducted on an open shelf in the laboratory protected from direct exposures to sunlight or wind. An approximate mean temperature of 85° F. and 50 per cent relative humidity prevailed in the laboratory during this investigation.

RESULTS.—Results of this study are shown in table 1. Endrin at a high dosage was the most effective chlorinated hydrocarbon tested against the sweetpotato weevil. All of the phosphorous formulations used, except malathion dust, were more effective than the remaining chlorinated hydrocarbons tested. All of the remaining chlorinated hydrocarbons and malathion dust resulted in some control of the sweetpotato weevil, and several of these materials could be used economically at higher dosages than that employed in these tests. In general, these laboratory results indicate that several available chemicals are sufficiently toxic to the sweetpotato weevil to justify further investigations in the control of this insect under field conditions. Information is needed on the residual effectiveness of these materials under various environmental conditions, the best methods and schedules to use in the applications of the insecticides, and the chemical residues on the edible roots of the sweet potato.

**Table 1.—Effectiveness of the indicated insecticides to the adult sweetpotato weevil.**

| INSECTICIDE[a] | PER CENT CONTROL[b] | |
|---|---|---|
| | Dust | Spray |
| Endrin | 99 | 73 |
| Methyl Parathion | 92 | 79 |
| EPN | 89 | 78 |
| Malathion | 58 | 79 |
| Dieldrin | 69 | 40 |
| Lindane | 59 | 46 |
| Aldrin | 49 | 55 |
| Heptachlor | 46 | 42 |
| DDT | 38 | 41 |
| Chlordane | 31 | 46 |
| Toxaphene | 28 | 31 |

[a] All insecticides applied at 0.5 pound active ingredient per acre.
[b] Forty-eight hours after insecticidal applications.

SUMMARY.—Laboratory toxicity tests conducted at College Station, Texas, in 1954 showed that several synthetic organic insecticides are highly toxic to the sweetpotato weevil. Endrin was the most effective chlorinated hydrocrabon tested, and it was as effective as methyl parathion or EPN, which were more effective than malathion, dieldrin, lindane, aldrin, heptachlor, DDT, chlordane, or toxaphene.

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## Cherry Fruit Fly Dispersion Studies[1]

S. C. JONES and LEW WALLACE,[2] *Oregon Agricultural Experiment Station, Corvallis*

Exploratory experiments were performed with radioactive phosphoric acid as a means of tagging cherry fruit flies, *Rhagoletis cingulata*, (Loew), for dispersion studies, in 1950. It was found after extensive laboratory experiments that radioactive phosphoric acid could be combined with sucrose as food for the flies without shortening their life. The flies ingested the food readily and with an initial count of 6000 per minute, could be detected up to 6 weeks with a portable survey meter. These experiments showed considerable variations in the amount of radioactivity retained by individual flies. Ten flies were picked at random in each of eight experiments and tested with a portable survey meter to determine the amount of radioactivity each fly attained after feeding on radioactive sucrose for 2 to 4 days. The average for 80 flies was 8893 counts per minute. These experiments also showed that flies receiving heavy dosages of radioactive phosphoric acid failed to oviposite in cherries. Experiments showed that the feces of the flies were radioactive as was the cherry juice and pulp of cherries in the cages where the radioactive flies were housed.

Experiments were undertaken in 1951 to determine if flies tagged with radioactive phosphoric acid could be used to determine the distance flies could be expected to migrate from a given point. A total of 2010 flies were made radioactive by feeding them radioactive sucrose. These flies were released at 10:00 A.M. on July 16, 1951, in an orchard which had been previously marked off by stakes 25 feet apart for the full length of the orchard. The young cherry trees varied in age from 2 to10 years old. They represented many varieties including both sweet and sour cherries. Many of the trees bore a full crop of cherries. The orchard was bounded on the north by a hop yard and on the

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Table 1.—Radioactive cherry fruit fly adults collected and distances from point of release.

| Distance from Point of Release (Feet) | Radioactive Flies | | | | | | | | | Total Flies |
|---|---|---|---|---|---|---|---|---|---|---|
| | July | | | | | | August | | | |
| | 18 | 19 | 23 | 24 | 27 | 31 | 1 | 2 | 9 | |
| 0 | 2 | | 3 | | | 2 | | | 9 | 16 |
| 45 | 2 | | | | | | | | | 2 |
| 55 | | 1 | | | | | | | | 1 |
| 105 | | 1 | | | | | | | | 1 |
| 155 | | | | | | | | 1 | | 1 |
| 205 | 2 | 1 | 1 | | 1 | 1 | 1 | | | 7 |
| 365 | | | 1 | | | | | | | 1 |
| 455 | | | | | 2 | 1 | 1 | | 3 | 7 |
| 555 | | 1 | | | | | | | | 1 |
| 942 | | | | 1 | | | | | | 1 |
| 560[a] | | | | 1 | | | | | | 1 |

[a] Orchard across beet field 100 feet in width.

south by a beet field 100 yards wide. Adjoining the beet field on the south, opposite the release orchard, was another orchard of cherries.

Three methods were employed for collecting the released flies. These were: (1) Three types of traps, all containing ammonium carbonate. (2) Manual collecting of flies with an insect net. (3) Spraying the trees with nicotine sulfate and collecting the flies from a canvas placed under the sprayed trees.

A total of 69 traps were placed in the experimental orchards. The traps were placed in the orchards as follows: Two at the 50-foot mark and one at the 75-foot mark on July 16. An additional 38 traps were placed in trees on July 17. Beginning at the 345-foot mark, two cages were placed at 50-foot intervals to the 525-foot marker. From the 525-foot marker two traps were placed 50 feet apart to the 625-foot marker. Five were in cherry trees 942 feet from the west end of the orchard. Ten were placed along the north edge of the orchard across the beet field. Two traps were placed in a cherry tree 865 feet north of the release point. Six McPhail traps containing ammonium carbonate were hung in trees, at 50-foot intervals from the point of release. Fourteen fly paper traps were set out, two each, at 50-foot intervals from the point of release on July 18.

The dispersal studies were concluded on August 9. Selected sour cherry trees distributed through the orchard were sprayed with nicotine sulfate 1 quart, whale oil soap 5 pounds, to 80 gallons of spray. Canvas was spread under the sprayed trees and the knocked-down flies were collected from the canvas and tested for radioactivity. Trees were sprayed at the following distances from the release point: 0, 125, 155, 195, 255, 455, 545, and 725 feet.

A total of 39 radioactive flies were recovered. Fourteen of these were taken at the point of release. Seven were taken 205 feet from the point of release, one at 555 feet and one 942 feet from the point of release. The latter was recovered 8 days after the flies were released. One fly was taken across the beet field 560 feet from the point of release.

The preliminary laboratory experiments and mass tagging of the flies were conducted at the Laboratory of the former U. S. Bureau of Entomology and Plant Quarantine, at the Corvallis Airport. A. W. Lindquist, Entomologist in charge of the laboratory, cooperated by making available laboratory space, and Geiger counters. Joseph S. Butts, Head, Agricultural Chemistry Department, Oregon State College, obtained radioactive phosphoric acid for the experiment through arrangements with the Atomic Energy Commission.

## Fumigation Tests with Ethylene Dibromide for the Control of Cherry Fruit Fly Eggs, Larvae and Puparia[1]

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Experimental fumigation with ethylene dibromide for the control of eggs, larvae, and puparia of the cherry fruit fly, *Rhagoletis cingulata* (Loew), was conducted during the summers of 1953 and 1954. This work was done at the request of the Oregon and California state departments of agriculture. Jones & Schuh (1953) found that methyl bromide gave complete control of the eggs, larvae, and puparia only when heavy dosages and long exposures were used.

All fumigation tests were conducted in well insulated fumigation chambers with 250 cubic foot capacity. The dosages in the following tests were based on 1,000 cubic feet of space. To simulate commercial fumigation where absorption is a factor the chamber was partially filled with boxes of excelsior.

FUMIGATION OF EGGS.—Eggs were obtained for the tests by caging gravid female flies on cherries which had been dipped in puritized agricultural spray to prevent brown rot and molds. From 19 to 39 cherries were used in each test, each lot containing an average of 244 eggs.

Egg fumigation tests were conducted on July 24, 27, 28, 30, August 3, 6, and 10, 1954. The dosage and fumigation period was ½ pound for 2 hours with temperatures for the various tests ranging from 64° F. to 77° F. No larvae hatched from any of the seven tests while an average of 36 larvae hatched in each of the seven checks.

FUMIGATION OF LARVAE.—Fumigation tests were conducted on July 30, 31, and August 1 and 7, 1953 for the control of larvae. The tests were set up as follows: (1) Twenty-five mature larvae were placed in ½-pint, open-end, food containers. The ends of the containers were closed with double thickness cheesecloth. (2) Twenty-five mature larvae were placed in individual cherries which were placed in open-end quart containers closed by cheesecloth. (3) Seventy-five infested cherries were placed in 1-quart open-end containers. The number of larvae in the cherries was unknown. Boxes of excelsior, together with three 50-pound lugs of cherries, were placed in the same fumigation chamber.

The dosage of ethylene dibromide and period of fumigation was as follows: ½ pound for a period of 2 and 3 hours; 1 pound, for 2 hours; and 2 pounds, for 2 hours. At the end of a 24-hour period after fumigation was completed, the larvae were examined for mortality. All the larvae, both inside and outside the cherries, were killed by both the minimum and maximum dosages and exposures.

Two boxes of heavily infested cherries were fumigated on August 8. The cherries were infested with larvae of all ages. The dosage of ethylene dibromide and length of the fumigation periods were ½ pound for 2 hours and ½ pound for 3 hours. One box of infested cherries was left untreated as a check. Six 50-pound lugs of cherries and a large box of excelsior were placed in the fumigation chamber and fumigated together with the infested cherries to approximate commercial practice.

All the fumigated larvae died within 24 hours after fumigation. A total of 380 dead larvae were counted in and outside of the cherries fumigated with ½ pound of ethylene dibromide for 2 hours. A total of 291 larvae died in the cherries which were fumigated with ½ pound of ethylene dibromide for 3 hours. A total of 339 larvae was counted in the untreated lot; 105 of these pupated, 156 were found alive, and 78 died.

FUMIGATION OF PUPARIA.—A total of 600 cherry fruit fly puparia was sifted from the soil under cherry trees during the winter and spring of 1953. One hundred puparia were used for each concentration and exposure. Concentrations of ethylene

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dibromide and period of fumigations were: ¼ pound, ½ pound, and 1 pound for 2 hours, and 2 pounds for 2 hours. One lot of 100 puparia was a check.

Results obtained were based on the number of flies emerging from the puparia. No flies emerged from puparia fumigated with ½ pound or over for exposure periods of 2 hours or more. Four flies emerged from puparia fumigated for 2 hours with ¼ pound of ethylene dibromide. Thirty-eight flies emerged from the check. The temperatures during fumigation varied from 70° F. to 73° F. The puparia in each test were placed in the same containers as were used for eggs and larvae tests.

TASTE TESTS.—Fresh Bing cherries were treated as follows: ½ pound of ethylene dibromide for 2 hours; ½ pound for 3 hours; 1 pound for 2 hours and 2 pounds for 2 hours. After being treated, the cherries were placed in a cool room at 34° F. until taste tested. Taste tests were held four times a day for 4 consecutive days.

For each test, 100 cherries were chosen at random from each treatment, and 200 cherries from the untreated lot. The cherries were washed, pitted, then ground in a coarse food grinder to insure a composite sample. The ground cherries were served in small coded cups to the tasters seated in isolated testing booths. One untreated, or reference sample, and five coded samples were presented to the taster at one time.

The tasters were members of the Food Technology staff or graduate students who are experienced tasters.

Four days after fumigation there was a slight change of flavor in the cherries fumigated with ½ pound of ethylene dibromide for 2 hours. The taste tests indicated, however, that the flavor change was less each day after fumigation. Off-flavor was evident in cherries fumigated with dosages over 1 pound for 2 hours. Taste testing was done under the supervision of Lois Sather, research assistant for the Food Technology Department, Oregon State College in cooperation with the author. The data were analyzed by L. D. Calvin, Oregon Experiment Station statistician.

SUMMARY.—Fumigation tests with ethylene dibromide showed that the eggs, larvae, and puparia of the cherry fruit fly, *Rhagoletis cingulata* (Loew), were all killed by a dosage of ½ pound of ethylene dibromide for a period of 2 hours. Heavier dosages and longer fumigation exposures also killed the eggs, larvae, and puparia while puparia fumigated with ¼ pound for 2 hours were not all killed.

Taste tests showed a slight change of flavor 4 days after fumigation with ½ pound of ethylene dibromide for 2 hours. A definite off-flavor occurred when dosages over 1 pound of ethylene dibromide were used.

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## Biological Notes on *Tabanus abactor* Phil. and *equalis* Hine[1]

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*Tabanus abactor* Phil. is the most pestiferous and abundant horse fly in Oklahoma. It is also capable of transmitting anaplasmosis, one of the most important diseases of cattle in the United States (Howell *et al.* 1941). Besides Oklahoma, it has been collected only in Kansas, Arkansas, and Texas. The larval habitat of this horse fly has not been previously recorded; so the finding of eight larvae in Oklahoma and four in Texas is of interest. Those taken in Oklahoma were collected from dry grass-covered soil beneath a small chittimwood tree, *Bumelia lanuginosa* (Michx.) Pets., where standing water would not be found. The four larvae taken in Texas were found in very dry leaf-covered soil beneath a blackjack oak, *Quercus marilandica* Muench., just below the crest of a hill where rain water would quickly run off. None of the larvae were buried more than an inch in the soil.

The larvae of this species are white, show no typical markings, and are very sluggish compared with other larvae of this genus. One larva was 6 mm. long when collected in October, but before pupation the following July it had attained a length of 22 mm. Pupation occurred beneath the surface of the medium and lasted 10 days. This evidence, if not atypical, indicates that the species may have a one-year life cycle. Soil from the habitat was utilized as a rearing medium, and both stable fly larvae and earthworms were readily accepted as food.

The only egg masses observed were those deposited by caged females. These eggs were in gray, double-tiered, very loose masses or scattered on the sand on the floor of the cage. No eggs were found on the leaves, twigs, grass, or screen wire of the cage. Masses contained from 40 to 175 with an average of 93 eggs. The incubation period of this species is approximately 6 days.

The average weight of 50 unfed *abactor* females was 68.2 mg.; after feeding their average weight was 246.2 mg. It was found, using 1.060 as the specific gravity of horses' blood, that the fly consumes 0.168 ml. of blood at a single engorgement.

*Tabanus equalis* Hine, which is common in the eastern part of Oklahoma, also ranks in the five most important species found in the State. It superficially resembles *T. sulcifrons* Macq. but is abundant earlier in the season. It has been taken from May 22 to August 12. The adults are most abundant in June and the first 2 weeks of July.

No egg masses were collected in the field or obtained under laboratory conditions, but Schnorrenberg (1932) described the egg mass as resembling "one side of a minature honey comb; the eggs are laid in one layer, perpendicular to the object upon which they are attached."

Thirty-eight larvae have been collected. The larvae are cylindrical and have a dull-yellow coloration not found in any other collected species. The contrasting dark-brown mandibles of the sluggish larvae are usually retracted and seldom seen. Full-grown larvae are approximately 34 mm. long, and the pupal stage lasts about 14 days.

Larvae were collected from seven localities which were very similar. The soil was sparsely covered with low grass and shaded by elm trees, *Ulmus americana* L. No standing water would ever be present, as the habitats were sufficiently sloping to provide excellent drainage. The larvae were widely dispersed in the soil and occurred from the surface beneath leaf cover to a depth of 4 inches.

Soil from the habitat was employed as a rearing medium and earthworms were utilized as food. The larvae developed slowly and apparently were less aggressive than many of the cannibalistic species. Two larvae were placed in the same container in the absence of food for 3 weeks without harm to either larva.

Apparently both *abactor* and *equalis* developed in areas where standing water is seldom found. This is in marked contrast to most tabanids, which are found where free water is present most of the time, such as streams, lake margins, ponds, and seepage areas. Schomberg (1952) demonstrated that *sulcifrons* also develops in dry situations. Thus it has been shown that three of the five most important species of horse flies in Oklahoma may develop in a dry habitat in marked contrast to most tabanids.

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## Response of Insects to Three Sources of Black Light[1]

THEODORE R. PFRIMMER, *Entomology Research Branch, Agr. Res. Serv., U.S.D.A.*[2]

The development of some new types of lamps in the last few years has stimulated interest in the possible use of light traps in insect surveys. Lamps filled with argon or mercury vapor have been of particular interest, because these lamps radiate a considerable portion of their energy in the near-ultraviolet, or black-light, region of the spectrum. Various workers have established that most positively phototropic insects respond more readily to wave lengths in the near-ultraviolet and violet-blue regions than to those in the green-yellow and orange-red.

During 1954 studies were conducted at Brownsville, Texas, to compare the response of the different orders of insects to three types of lamps, all supplied by the General Electric Company—(1) a 15-watt BL fluorescent lamp, (2) a 15-watt BLB fluorescent lamp, and (3) three 2-watt S14AR-1 argon glow lamps. The spectral-energy distribution of these lamps is shown in table 1. "Fluoren" is the term proposed as the unit of measurement for radiant energy in the black-light region. The lumen is the unit of quantitative measurement for radiation in the visible region of the spectrum. All three lamps have approximately the same peak radiation point, but the proportion of energy radiated in the black-light and visible regions as well as the total radiation varies greatly. The argon glow lamp has a much lower output in the black-light range than the other lamps, and the BL fluorescent lamp has a much higher output in the visible region. The BLB fluorescent lamp has by far the highest ratio of fluorens to lumens, and the BL fluorescent lamp the lowest.

All the traps used were similar to the Minnesota trap in design but they differed from each other in certain respects. The trap containing the BL lamp was constructed of galvanized sheet metal, and the one containing the BLB lamp of sheet aluminum. Neither of these traps was painted. The trap containing the argon lamps was of sheet metal and had no top. The funnel of this trap was painted black, and the baffles a fluorescent green. The three argon lamps were mounted in a vertical row in the center of the baffles. The fluorescent lamps were mounted vertically in the center of their traps.

The three traps were grouped in a triangular arrangement within a few feet of each other. The argon lamps were about 3 feet and the fluorescent lamps about 6 feet above the ground. All the traps were operated by a single switch and were turned on at 5 P.M. and off at 8 A.M.

**Table 1.—Spectral-energy distribution of three types of black-light lamps.**

| Lamp | Black Light (2,800–3,800 A.) Fluorens | Visible Light (3,800–7,600 A.) Lumens | Radiation Peak A. |
|---|---|---|---|
| BL fluorescent | 1,800 | 145.4 | 3,500 |
| BLB fluorescent | 1,350 | 0.057 | 3,550 |
| Argon glow | 7 | 0.06 | 3,600 |

**Table 2.—Insects caught in three light traps in January, February, and March 1954.**

| Order | Number Caught | | | Per Cent of Total Catch for Each Trap | | |
|---|---|---|---|---|---|---|
| | BL | BLB | Argon | BL | BLB | Argon |
| Coleoptera | 29,976 | 43,791 | 2,239 | 57 | 43 | 28 |
| Diptera | 6,641 | 30,113 | 2,875 | 14 | 30 | 36 |
| Lepidoptera | 6,258 | 15,290 | 2,094 | 13 | 15 | 26 |
| Ephemerida | 5,514 | 8,139 | 291 | 11 | 8 | 4 |
| Hemiptera | 1,027 | 1,951 | 254 | 2 | 2 | 3 |
| Trichoptera | 502 | 810 | 213 | 1 | <1 | 3 |
| Hymenoptera | 453 | 720 | 23 | 1 | <1 | — |
| Homoptera | 442 | 670 | 37 | 1 | <1 | — |
| Orthoptera | 21 | 31 | 2 | — | — | — |
| Isoptera | 6 | 8 | 1 | — | — | — |
| Neuroptera | 2 | 2 | 0 | — | — | — |
| Total | 50,842 | 101,525 | 8,029 | 100 | 100 | 100 |

**Table 3.—Response of some species of moths to the three light sources, January–March 1954.**

| Species | Number Caught | | |
|---|---|---|---|
| | BL | BLB | Argon |
| *Ommatopteryx ocellea* | 883 | 3,115 | 388 |
| *Acontia aprica* | 54 | 80 | 17 |
| *Feltia subterranea* | 42 | 55 | 7 |
| *Heliothis armigera* | 103 | 84 | 11 |
| *Agrotis malefida* | 174 | 158 | 17 |

Table 2 shows the catches in the traps on 11 nights in January, 13 nights in February, and 18 nights in March 1954. Since some insects are seasonal in occurrence, the results might not be the same at some other time of the year.

The BLB trap caught twice as many insects as the BL trap and approximately 12½ times as many as the argon trap. How much of the difference was due to differences in energy radiation and how much to other factors, such as the difference in light reflection from aluminum and galvanized sheet metal, would be difficult to say. There seems to be little doubt that the small catch in the argon trap was due largely to the much lower intensity of radiation.

Eleven orders of insects were represented in the collections, but four orders—Coleoptera, Diptera, Lepidoptera, and Ephemerida—made up approximately 95 per cent of the total in each trap. Coleoptera were the most numerous in the BL and BLB traps, and Diptera in the argon trap. Between traps the proportion of Coleoptera and Ephemerida in relation to the other orders decreased as the total output of fluorens decreased, whereas the reverse was true of Diptera and Lepidoptera.

Although the BLB lamp attracted nearly 2½ times as many Lepidoptera as the BL lamp, the response of individual species varied a great deal, as shown in table 3. *Ommatopteryx ocellea* (Haw.) was attracted in by far the greatest numbers to the BLB lamp, and *Acontia aprica* (Hbn.) and *Feltia subterranea* (F.) in slightly greater numbers than to the BL lamp, but *Heliothis armigera* (Hbn.) and *Agrotis malefida* Guen. were attracted in slightly greater numbers to the BL lamp. These data indicate the complexity of this situation. Each species or group of species is a separate problem requiring extensive study to determine the most efficient and the most economical light source and trap design, if light traps are to be used successfully as survey tools.

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[2] In cooperation with the Texas Agricultural Experiment Station and the Agricultural Engineering Research Branch, U.S.D.A. Special acknowledgement is made to J. P. Hollingsworth of that Branch for assistance in these studies.

## Species and Relative Abundance of Flies Collected from Chicken Manure in Alabama[1]

H. B. CUNNINGHAM, C. D. LITTLE, S. A. EDGAR, and W. G. EDEN,[2] *A.P.I. Agricultural Experiment Station, Auburn*

The breeding of flies in chicken manure has been a problem for many years. This problem has been increased by the practice of housing hens in individual cages, which allows droppings to accumulate under the cages. These manure piles provide attractive sites for fly oviposition and development.

References in the literature on the species of flies breeding in poultry manure are limited. Illingworth (1923) reported 12 species of Diptera from poultry manure. *Sarcophaga fuscicauda* Bottcher was the most abundant species, followed by the house fly, *Musca domestica* L., and the stable fly, *Stomoxys calcitrans* (L.). Later Tanada *et al.* (1950) reported 24 species of flies belonging to 14 families breeding in chicken manure. They found the house fly to be the most abundant species, followed by *Fannia pusio* (Wied.). *Hermetia illucens* (L.) ranked sixth in abundance and the stable fly was ninth. In a similar study Kartman *et al.* (1950) reported over 20 species of Diptera breeding in chicken manure. All of the above references dealt with flies breeding in Hawaii.

In an effort to determine the species and relative abundance of flies breeding in poultry manure in Alabama, over 1,000 collections were made from mid-1950 through 1952. The flies were collected in traps equipped with metal rims around the bottom edges. The metal rims were pressed firmly into the manure piles, and the emerging flies were removed at periodic intervals.

The results of the studies are presented in table 1. Forty-five species belonging to 18 families were collected.[3] The relative abundance of 36 species of flies taken in 142 trappings made throughout the calendar year of 1952 is shown in the table. *Musca domestica* L. was by far the most common species, comprising 50.2 per cent of the total. It was followed in order by *Fannia pusio* (Wied.), 21.2 per cent; *Fannia canicularis* (L.), 10.9 per cent; *Muscina stabulans* (Fall.), 9.5 per cent; and *Hermetia illucens* (L.), 3.0 per cent. The other 31 species occurred in considerably fewer numbers. In other trappings, *Leptocera exiquella* Spuler and *L. fontinalis* (Fall.) ranked among the most common species.

**Table 1.—Species and relative abundance of flies collected from chicken manure, Auburn, Alabama.**

| Species Collected[a] 1950–1952 | Relative Abundance, 142 Collections, 1952 | |
|---|---|---|
| | No. of Flies | Per Cent of Total |
| *Musca domestica* L. | 4,054 | 50.198 |
| *Fannia pusio* (Wied.) | 1,710 | 21.174 |
| *Fannia canicularis* (L.) | 879 | 10.884 |
| *Muscina stabulans* (Fall.) | 767 | 9.497 |
| *Hermetia illucens* (L.) | 241 | 2.984 |
| *Stomoxys calcitrans* (L.) | 111 | 1.374 |
| *Hydrotaea* sp. | 95 | 1.176 |
| *Ophyra leucostoma* (Wied.) | 57 | 0.706 |
| *Dendrophaonia hilariformis* Stein | 41 | 0.508 |
| *Sepsis punctum* (Fab.) | 19 | 0.235 |
| *Psychoda alternata* Say | 11 | 0.136 |
| *Drosophila buscki* Coq. | 10 | 0.124 |
| *Chyromya* sp. | 8 | 0.099 |
| *Milichiella* sp. | 8 | 0.099 |
| *Sarcophaga* sp. | 8 | 0.099 |
| *Eristalis tenax* Fab. | 7 | 0.087 |
| *Scatopse fuscipes* Mg. | 6 | 0.074 |
| *Fannia* sp. | 6 | 0.074 |
| *Fannia manicata* (Mg.) | 5 | 0.062 |
| *Sarcophaga pectinata* Ald. | 4 | 0.050 |
| *Chrysomyza demandata* (Fab.) | 4 | 0.050 |
| *Muscina assimilis* Fall. | 3 | 0.037 |
| *Leptometopa latipes* (Mg.) | 3 | 0.037 |
| *Scatopse notata* (L.) | 3 | 0.037 |
| *Meroplius starcorarius* R-D. | 2 | 0.025 |
| *Procthyliza xanthostoma* Walk. | 2 | 0.025 |
| *Drosophila* sp. | 2 | 0.025 |
| *Oscinella* sp. | 2 | 0.025 |
| *Piophila nigriceps* Mg. | 1 | 0.012 |
| *Desmometopa M-nigra* (Zett.) | 1 | 0.012 |
| *Euxesta notata* (Wied.) | 1 | 0.012 |
| *Allotrichoma abdominalis* Will. | 1 | 0.012 |
| *Leptocera* sp. | 1 | 0.012 |
| *Psychoda* sp. | 1 | 0.012 |
| *Atrichopogon* sp. | 1 | 0.012 |
| *Tosmosvaryella* sp. | 1 | 0.012 |
| *Callitroga macellaria* (Fab.) | | |
| *Phaenicia sericata* (Mg.) | | |
| *Gymnopa tibialis* (Cress.) | | |
| *Pseudoleria pectinata* (Lw.) | | |
| *Milichiella lacteipennis* (Mg.) | | |
| *Synthesiomyia nudiseta* (van der Wulp) | | |
| *Leptocera exiquella* Spuler | | |
| *Leptocera fontinalis* (Fall.) | | |
| *Fannia femoralis* Stein | | |
| Total | 8,076 | 99.997 |

[a] Species listed without numbers were taken in trappings other than the 142 trappings listed for 1952. Numerous specimens of several species were collected.

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[1] Accepted for publication August 9, 1955.

[2] The data presented herein are taken from theses prepared by H. B. Cunningham and C. D. Little as partial fulfillments for the degrees of Master of Science at the Alabama Polytechnic Institute. The researches of these authors were directed by W. G. Eden and S. A. Edgar, respectively.

[3] The authors gratefully acknowledge the assistance of W. H. Anderson, C. W. Sabrosky, Alan Stone, and W. W. Wirth of the Insect Identification and Parasite Introduction Section, Entomology Research Branch, U.S.D.A., in making many identifications and checking all others.

## The Apple Seed Chalcid, Its Distribution and Potentials as a Pest of Apples in North Carolina[1]

G. F. TURNIPSEED and T. B. MITCHELL, *North Carolina State College, Raleigh*

The apple seed chalcid, *Torymus druparum* Boh., was first found in North Carolina in the fall of 1953. Cushman (1916) states, "The apple-seed chalcid apparently occurs throughout the northern tier of states, at least from Vermont to Michigan. It has not been found in Ohio or Indiana." Cushman found this chalcid as far south as Clearfield, Pa. and states that "it is probably distributed throughout the eastern part of the country wherever small seedling apples (*Malus sylvestris*) are to be found."

In the fall of 1954 a survey of representative orchards was

[1] Accepted for publication April 25, 1955.

Table 1.—Apple seed chalcid survey of North Carolina, 1954.

| County | Number of Orchards | |
|---|---|---|
| | Surveyed | Infested |
| Alexander | 3 | 1 |
| Avery | 4 | 4 |
| Buncombe | 2 | 1 |
| Haywood | 9 | 4 |
| Henderson | 8 | 2 |
| Mitchell | 3 | 3 |
| Wake[a] | 1 | 0 |
| Watauga | 2 | 1 |
| Wilkes | 10 | 2 |
| Total (9) | 42 | 18 |

[a] Not in major apple-growing area of N. C.

made in the apple-growing area of North Carolina (Table 1). Forty-two orchards were inspected, and 18, or 44%, were found to be infested. These infestations varied from light to moderately heavy. The northwestern section was moderately infested. The eastern section was only slightly infested. This indicates that the apple seed chalcid might become more of a pest in the higher elevations of the apple-growing area of the state. Of the 18 orchards infested, 15 of the orchardists used the lead arsenate program, one used the parathion, and one orchard was abandoned. The apple seed chalcid was found in the following commercial varieties of apples: Golden Delicious, Red Delicious, Red Winesap, Stayman Winesap, Rome and black Ben Davis. It was also found in a planting of sweet crab apples. From this survey there was no indication that this pest preferred any one variety.

Larvae of the apple seed chalcid were found only in small apples. The infested fruit grew very little after oviposition by the adults. Those infested could not be distinguished from the poorly pollinated fruit unless the apple was cut horizontally to expose the seed and core. If there were no seed developing, there was incomplete pollination. If the seed had started and was developing slowly with the microphyte end of the seed thin and the other end fat and soft, these seeds never failed to yield the fat soft larva of the apple seed chalcid. Thus, the growth of the infested apple was seriously retarded. The retarded fruit remained on the tree, colored and ripened, but remained small throughout the season.

This pest was not a serious problem in 1954 and did not materially reduce total yield. This was due to the extremely heavy set of fruit in 1954. However, the apple seed chalcid might become a pest of economic importance in North Carolina in the years of light set of fruit.

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## Further Experiments with Insecticides for Control of Green June Beetle Larvae[1]

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Two earlier papers dealing with the use of organic insecticides for the control of green June beetle larvae, *Cotinis nitida* (L.), in tobacco plantbeds have been published by the writer (Dominick 1950, 1952). The results reported in this paper were obtained from a continuation of these experiments during the period 1952–54, in which information was obtained on the control of third-instar larvae with several organic insecticides, using different methods of application.

Table 1.—Control of green June beetle larvae in tobacco plantbeds with organic insecticides.

| Insecticide | Applied as | Pounds per 100 Square Yards[a] | Larvae Recovered | Per Cent Reduction[b] |
|---|---|---|---|---|
| | | *1952* | | |
| Parathion, 1% | dust | 2 | 202 | 96 |
| Lindane, 1.5% | dust | 2 | 125 | 87 |
| Potasan, 1% | dust | 2 | 136 | 62 |
| Malathion, 5% | dust | 2 | 89 | 8 |
| Demeton, 1% | dust | 2 | 114 | 4 |
| Parathion, 15%, w.p. | drench | 0.125 | 126 | 91 |
| | | *1953* | | |
| Parathion, 1% | dust | 2 | 124 | 98 |
| Parathion, 1% | granules | 2 | 104 | 96 |
| Lindane, 1% | granules | 2 | 104 | 94 |
| Lindane, 1% | dust | 2 | 90 | 92 |
| Dilan, 5% | dust | 2 | 108 | 92 |
| Chlordane, 5% | granules | 5 | 108 | 75 |
| | | *1954* | | |
| Lindane, 1% | dust | 2 | 78 | 94 |
| Parathion, 1% | dust | 2 | 96 | 94 |
| Dilan, 5% | dust | 2 | 53 | 77 |
| Parathion, 15%, w.p. | drench | 0.25 | 66 | 97 |
| Dilan, 50%, w.p. | drench | 0.25 | 73 | 90 |
| Malathion, 25%, w.p. | drench | 0.50 | 69 | 86 |

[a] Formulation.
[b] After 21 days in 1952, 30 days in 1953, and 24 days in 1954.

Method.—Tobacco plantbeds 1 square yard in size were located on infested soil. They were replicated four times in a randomized block design. The plantbed boards were placed in the soil to a depth of 4 inches to discourage larval migration, and an effort was made to equalize the populations within plots by adding third-instar larvae to those showing little or no grub activity. Tobacco was seeded in the various plots during the month of February in accordance with the general farm practice. The treatments were applied to the soil surface late in the afternoon on warm days following evidence of larval activity. Insecticides used as a drench were applied with a sprinkler can at the rate of 50 gallons per 100 square yards of plantbed area. The dusts were applied by hand after being mixed with a small amount of slightly moist sand to prevent drift and to give a more uniform distribution. The plots were examined for dead larvae at intervals of 2 days following treatment, and the final results were determined by making an examination of the soil for living and dead larvae.

Experiment in 1952.—The object of the 1952 tests was to compare parathion and lindane with three of the newer phosphate insecticides. The materials were applied to the soil surface on April 10 and the final results determined on May. 1 The insecticides used and the results obtained are presented in table 1. In the tests, 1 per cent parathion dust gave the greatest reduction in green June beetle larvae. The parathion drench was slightly less effective than the dust treatment at the dosage used. Potasan, malathion and demeton gave ineffective results in the tests. Tobacco plants in plots treated with malathion and demeton were completely destroyed by larval activity. Parathion and lindane gave rapid control, a high percentage of the larvae being killed during the first 6 days following treatment.

Experiment in 1953.—Several insecticides were used as dust and granulated formulations in the 1953 tests. Under favorable conditions granulated insecticides do not adhere to the foliage but fall through to the soil surface. From the standpoint of the operator, granulated insecticides may be less hazardous than dusts; however, the application problem in tobacco plantbeds is greater with the granulated materials. The insecticides were

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applied on April 10 and observations were made during the next 30 days.

The materials used and the results obtained are given in table 1. The two parathion formulations gave the highest percentage of reduction in green June beetle larvae, there being little difference in the control obtained with the two materials. As in the previous experiment, a high percentage of the larvae were killed during the first 6 days following treatment. Lindane, 1 per cent as a dust and as a granulated formulation gave effective control. Dilan, 5 per cent dust, was also effective in the tests, the reduction being 92 per cent. Chlordane, 5 per cent granulated, was the least effective of the materials tested; its slow action allowed extensive plant damage, although it eventually gave a reduction of 75 per cent. Approximately 10 per cent of the plants in plots treated with lindane and chlordane showed phytotoxicity.

EXPERIMENT IN 1954.—The object of the 1954 experiments was to test several materials used as dusts and drenches. The insecticides were applied on April 7, at which time surface activity was noticeable. Observations were made over a period of 24 days following treatment, and final results were determined by making examinations of the soil.

The materials used and the results obtained are given in table 1. Among the dusts, parathion and lindane gave a similar reduction of 94 per cent, whereas Dilan, 5 per cent dust, was not effective. Approximately 5 per cent of the plants in plots treated with lindane showed phytotoxicity. Among the insecticides used as a drench, parathion gave the most rapid and effective control. Both Dilan and malathion were much slower in action and less effective than parathion.

SUMMARY.—Experiments were conducted at Chatham, Virginia, during 1952–54 for the control of third-instar green June beetle larvae, *Cotinis nitida* (L.), in tobacco plantbeds. Parathion was the most satisfactory insecticide tested from the standpoints of effective rapid control and phytotoxicity. One properly timed application of this material as a dust, a granulated formulation, or a drench gave excellent control. None of the insecticides except lindane and chlordane caused any apparent injury to the young seedlings.

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## Biology of *Anacampsis innocuella* (Zeller), a Leafroller on Aspen[1]

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In 1952 the writer discovered a dense population of an insect rolling the leaves of aspen near New Philadelphia in northeastern Ohio. Moths issuing from the leafrolls later in the season were identified as *Anacampsis innocuella* (Zeller).[2] This report is based upon occasional observations made at the above site through the 1952 and 1953 seasons.

The infested stand consisted of about 30 trees of *Populus grandidentata* Michaux, the bigtooth aspen, growing on the spoils bank of an old coal strip mine. The trees were of various ages up to an estimated 15 or 20 years. No particular age or size was affected more than any other. Vertical distribution of rolled leaves appeared to be random.

Emergent larvae began feeding in April of both years, about the same time that the trees began leafing out. Leafing out starts in the tops and progresses slowly downward. By the middle of May, leafrolls were seen on the higher branches of older trees. Leaves present at this stage were judged to be up to two-thirds the size normally attained during the season. The leafrolls present consisted of only one leaf. Later in the season many rolls are composed of more than one leaf. On the lower branches the young larvae were feeding on newly opened buds and tying together leaflets. Terminals injured in this manner contained from 3 to 15 larvae each. Two types of larvae were noted at this time; the easily distinguished one of *Anacampsis innocuella*, with dark pigmented pinacula, and another that was less distinctive and unidentified.

Pupae of *A. innocuella* were first observed the last week in May. By the middle of June pupation was nearly completed and the unidentified larvae had practically disappeared. Prior to pupation, about a third of the larvae severed their leafrolls from the trees. The petioles were chewed through at a point about three millimeters from their connection with the leaf blade. The severed leafrolls consisted almost invariably of but one leaf, while a majority of the nonsevered rolls consisted of two or more leaves. Probably the larva severs only one leaf; thus multiple-leaved rolls would tend to remain on the tree. The number of leaves comprising 300 nonsevered leafrolls is as follows: one leaf, 43%; 2 leaves, 32%; 3 leaves, 16%; 4 or 5 leaves, 9%.

Occasionally, where several leaves comprised one roll, two, and rarely three, leafroller larvae or pupae were found in different parts of the same roll. Conversely, in a collection of 209 rolls, more than half were found to contain no leafrollers. These facts are strong evidence that the larvae have wandering habits.

Leafrolls removed on June 5, 1952 and June 22, 1953 to an insectary at the Experiment Station in Wooster, located about 35 miles northwest of the study site, began yielding adult moths on June 18 and June 23, respectively. Moths continued to emerge both seasons for about 2 weeks in the insectary. In the middle of July, 3 weeks or more following initial insectary emergence, active moths were noticed at the study site. It seems likely that the eggs are deposited in the summer on twigs, and that the egg stage is the wintering form of the insect.

Because of numerous secondary invaders, several of which were lepidopterous, all parasites that emerged from the rolled leaves in the insectary cannot be considered to have developed on *A. innocuella*. However, by direct observation, *Spilochalcis flavopicta* (Cress.) and *Dimmockia incongrua* (Ash.) are known to have emerged from the leafroller pupae. Probable leafroller parasites were *Apanteles epinotiae* Viereck, *Itoplectis conquisitor* (Say), and *Brachmeria ovata* (Say). The following species appeared also, but their host relationships are uncertain: *Chorinaeus* sp., *Elachertus* sp., *Exochus* sp., *Microgaster comptanae* Viereck, *Pimplopterus* sp., and *Sympiesis* sp. All of the parasite species are hymenopterous.[3]

The percentage of parasitization of larvae and pupae was low. Even with all of the above species of parasites included in a computation representing both seasons, the resulting figure amounts to only 11%. Also, the seasonal history observations made at intervals during larval development did not reveal any early maturing larval parasites.

The leaves are nearly always rolled parallel to the midrib (Figure 1), but the leaves of 2% of the rolls examined had been rolled perpendicular to the midrib. The softer tissues of the rolled leaves are consumed by the larvae. When unrolled, injured leaves give the impression of having been skeletonized. In rolls composed of more than one leaf, only the innermost one or two leaves were fed upon. Leaves developing from buds injured by the younger larvae were ragged in appearance and showed nu-

[1] Accepted for publication May 20, 1955.

[2] Lepidoptera, Gelechiidae. Determination by Dr. J. F. G. Clarke, Curator of Insects, U. S. National Museum.

[3] Determinations of Chalcidoidea, Braconidae, and Ichneumonidae made by B. D. Burks, C. F. W. Muesebeck, and L. M. Walkley respectively, of the Insect Identification and Parasite Introduction Section, Entomology Research Branch, U. S. Dept. of Agr., Washington, D. C.

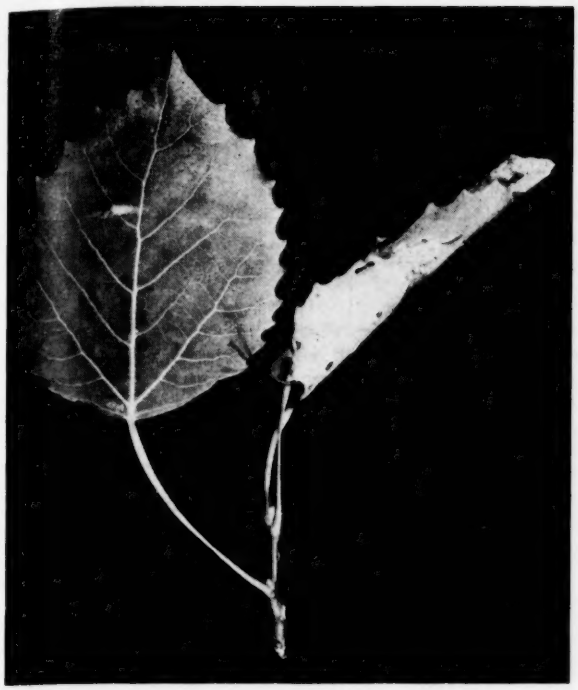

FIG. 1.—A normal leaf and a leafroll caused by *Anacampsis innocuella* (Zeller) from bigtooth aspen.

merous punctures. The density of the leafrolls on the trees was estimated during June to be about one per square foot of surface foliage. However, no effect on the vitality of any of the trees was observed.

No survey for the distribution of the leafroller was made in Ohio, but typical leafroller work was seen at two other points in the northern half of the state. At neither of these sites did the leafroller population approach the density of that at the study site.

A search of the literature revealed but little previous work on the biology of the insect. Davis (1918) noted the larval habit of severing leafrolls and recorded the presence of larvae and pupae in leaves of *Populus grandidentata* on Long Island, June 21, 1917. He quoted H. G. Dyar who had earlier given the broad leaved cottonwood, *P. wislezeni* (Watson), as a host. Forbes (1918) corroborated the severing observation and added the quaking aspen, *P. tremuloides* Michaux, to the host list. *Populus alba* Michaux, the white poplar, is noted as a host on Nantucket Island, where the moths are on the wing in July (Jones & Kimball 1943). Schaffner (1950) gives the distribution of *Anacampsis innocuella* as Massachusetts to Colorado and Texas. In addition, Procter (1946) has reported the insect from Maine where the flight period was from July 10 to August 10.

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## DDVP as a Toxicant in Poison Baits for House Fly Control[1]

JOHN W. KILPATRICK and H. F. SCHOOF[2]

In reporting the discovery of a new organic phosphorus compound DDVP (0,0-dimethyl 2,2-dichlorovinyl phosphate), Mattson, *et al.*,[3] indicated it to be equivalent to parathion in its toxicity to house flies but to have only one-sixth the $LD_{50}$ value of parathion against male rats. In view of its potency against *Musca domestica*, DDVP was tested as a toxicant in poison baits used for house fly control.

METHODS.—During late summer of 1954 poison baits containing DDVP were evaluated at two dairies near Savannah, Georgia. One dairy exhibited an extremely high fly potential. Approximately 250 cows and 50 to 75 penned calves and pigs were maintained at this dairy. Sanitation in animal pens was poor with manure being removed only once or twice per year. Poison bait treatments were applied to this dairy as needed. The second dairy possessed a low fly potential category and was treated on a weekly basis.

The principal formulation tested consisted of 0.1% DDVP in a 10% sugar solution. In addition a 0.01% solution was tested as single applications.

At each dairy the liquid bait was applied in the milking barn, along a ledge (4″ wide) above the feed boxes and to the floor as a single strip (6″ wide) the length of the barn. The outside portions of feed boxes in calf pens and the doorways of feed room also received treatment. The dry bait was exposed in shallow trays only in the feed room and calf pens. The effectiveness of the bait treatments was evaluated by making grill counts at four stations in the milking barn and feed room. At each station five counts were taken and the highest count from each station used to obtain an average fly index. Outside or calf pen counts were not included in the evaluation; however they were recorded.

RESULTS.—The DDVP-bait treatments at the dairy of high fly potential showed spectacular and immediate reduction of house fly indices (Table 1, Barn 1). Three hours after the initial treatment of a liquid bait, fly populations were reduced from an average grill count of 233 to an average count of 3. Pretreatment calf pen counts approached an average index of 2,000 flies whereas 3 hours later the highest count obtainable was only 7 flies. Bait treatments were repeated at intervals of 2 to 5 days. After some applications, fly densities rose to unsatisfactory levels within 48 hours; after others 3 to 5 days elapsed before unsatisfactory indices again were noted.

A single application of a 0.01% liquid DDVP bait produced satisfactory results but its effectiveness apparently was completely gone in less than 24 hours as compared to approximately 48 hours effectiveness observed with the 0.1% DDVP formulations.

At the dairy with the low fly potential, an immediate reduction of the house fly population was obtained with each poison bait treatment. In 3 hours the initial pretreatment count of 159 specimens was reduced to an average grill count of only 3 flies (Table 1, Barn 2). Low indices persisted for 2 days after each of the three applications but 3 to 7 days later the counts reflected unsatisfactory control.

[1] Accepted for publication April 22, 1955.

[2] From the Communicable Disease Center, Public Health Service, U. S. Department of Health, Education, and Welfare, Savannah, Georgia.

[3] Mattson, A. M., Janet T. Spillane, and George W. Pearce. 1955. Dimethyl 2,2-Dichlorovinyl phosphate (DDVP), an Organic Phosphorus Compound Highly Toxic to Insects. Jour. Agri. and Food Chem. 3(4): 319-21.

**Table 1.—Reduction of house fly densities at dairy barns with DDVP poison baits.**

| Date Treated | Per Cent Concentration | Quarts Used | No. of House Flies Before Treatment | No. of House Flies at Indicated Intervals after Treatment | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 2–3 Hrs. | 1 Day | 2 Days | 3 Days | 5 Days | 6 Days | 7 Days |
| **Barn 1** | | | | | | | | | | |
| 8/27 | 0.1 | 8 | 233 | 3 | — | — | 17 | | | |
| 8/30 | 0.1 | 12 | 17 | 1 | 6 | 27 | | | | |
| 9/2 | 0.1 | 2 | 27 | — | 2 | — | — | 31 | | |
| 9/7 | 0.1 | 4 | 31 | — | 10 | — | 10[a] | | | |
| **Barn 2** | | | | | | | | | | |
| 8/25 | 0.1 | 2 | 159 | 3 | 3 | 13 | — | 19 | — | 61 |
| 9/1 | 0.1 | 2 | 61 | — | 2 | 6 | — | — | 103 | |
| 9/7 | 0.01 | 2 | 103 | — | 8 | — | 138 | — | 54[b] | |

[a] Counts of house flies 10 days (9/17), 16 days (9/23) and 23 days (9/30) after treatment were 10, 20, and 55, respectively.
[b] Counts of house flies 13 days (9/20) and 20 days (9/27) after treatment were 27 and 62, respectively.

Discussion.—The data from these preliminary studies demonstrate that DDVP offers considerable promise as a toxicant in poison baits for house fly control. As with the organophosphorus compounds commonly employed in fly baits such as malathion, L 13/59, and Diazinon, DDVP baits require frequent applications to insure continuous low fly densities. However, the limited findings suggest that the effective concentration of DDVP can be reduced well below the 0.1% level commonly utilized for these other organophosphorus compounds.

## Aphids Caught in Wind-Vane Traps with Openings of Different Sizes[1]

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G. W. Simpson and Mildred Covell,
*Maine Agricultural Experiment Station, Orono*

In studies at Presque Isle, Maine, of the flight habits and seasonal abundance of aphids that infest potatoes, a wind-vane trap described by Shands *et al.* (1942) was used. This trap was satisfactory when moderate numbers of aphids were in flight, but during periods of heavy flight excessive time was required to identify and count them. A study was therefore made to determine if the trap opening could be reduced during periods of heavy flight and adjustment made in the results without causing appreciable bias.

Two traps of the same design but of different size were operated from August 22 to September 28, 1945, on like stands about 25 feet apart in a clearing well removed from any obstructions to wind movement. One was the standard trap with an opening 19½ inches square, and the other had an opening 12 inches square. The ratio of the orifice area of the larger trap to that of the smaller one was 2.64. Openings of both traps were centered 12½ feet above ground level during operation. All insects were removed from both traps at about the same time each day. The winged aphids from each trap were preserved separately and stored until identification and counts could be made under a binocular microscope.

The numbers of winged aphids taken daily from each trap are shown in table 1. All but one of the missing dates were days in which the aphids were not removed because of rain. On September 4 both traps were emptied but the collection from one was lost. Of the potato-infesting species, the buckthorn aphid (*Aphis abbreviata* Patch) was most abundant, followed by the green peach aphid (*Myzus persicae* (Sulz.)) and the potato aphid (*Macrosiphum solanifolii* (Ashm.)).

**Table 1.—Numbers of winged aphids taken daily from large and small traps near Presque Isle, Maine, August 23 to September 28, 1945.**

| Date | Buckthorn Aphid | | Green Peach Aphid | | Potato Aphid | | Other Aphids | |
|---|---|---|---|---|---|---|---|---|
| | Large | Small | Large | Small | Large | Small | Large | Small |
| Aug. 23 | 256 | 561 | 26 | 37 | 5 | 9 | 5 | 29 |
| 24 | 1,239 | 658 | 80 | 43 | 43 | 27 | 24 | 11 |
| 25 | 1,654 | 926 | 200 | 111 | 116 | 47 | 35 | 19 |
| 28 | 539 | 1,089 | 901 | 711 | 325 | 284 | 37 | 27 |
| 29 | 1,746 | 939 | 170 | 57 | 56 | 57 | 125 | 61 |
| 30 | 3,924 | 1,975 | 676 | 311 | 388 | 127 | 219 | 121 |
| 31 | 19,240 | 4,080 | 1,900 | 388 | 2,500 | 574 | 296 | 61 |
| Sept. 3 | 4,633 | 1,899 | 272 | 96 | 298 | 64 | 40 | 32 |
| 5 | 359 | 416 | 119 | 123 | 46 | 68 | 13 | 23 |
| 6 | 1,389 | 1,574 | 476 | 278 | 262 | 167 | 167 | 83 |
| 7 | 1,290 | 631 | 163 | 128 | 70 | 65 | 89 | 64 |
| 8 | 1,416 | 1,113 | 316 | 190 | 82 | 43 | 106 | 70 |
| 9 | 4,759 | 2,405 | 1,500 | 659 | 604 | 256 | 392 | 174 |
| 10 | 709 | 280 | 504 | 253 | 70 | 32 | 29 | 16 |
| 11 | 3,536 | 2,455 | 1,734 | 730 | 51 | 45 | 207 | 120 |
| 12 | 2,807 | 1,542 | 3,484 | 1,536 | 40 | 23 | 123 | 70 |
| 13 | 2,343 | 1,123 | 1,110 | 618 | 20 | 5 | 163 | 76 |
| 14 | 295 | 158 | 133 | 123 | 14 | 15 | 44 | 30 |
| 16 | 2,073 | 973 | 527 | 303 | 9 | 11 | 78 | 47 |
| 17 | 85 | 24 | 36 | 16 | 0 | 3 | 5 | 7 |
| 18 | 69 | 54 | 50 | 28 | 2 | 3 | 14 | 4 |
| 20 | 131 | 85 | 269 | 162 | 0 | 2 | 18 | 11 |
| 21 | 160 | 82 | 107 | 41 | 0 | 3 | 19 | 9 |
| 22 | 141 | 48 | 130 | 38 | 0 | 1 | 58 | 25 |
| 23 | 18 | 10 | 6 | 3 | 0 | 0 | 5 | 1 |
| 24 | 54 | 19 | 62 | 28 | 2 | 2 | 32 | 6 |
| 25 | 53 | 50 | 39 | 33 | 2 | 1 | 67 | 33 |
| 26 | 28 | 50 | 15 | 12 | 1 | 1 | 96 | 87 |
| 27 | 10 | 5 | 4 | 2 | 0 | 0 | 53 | 36 |
| 28 | 4 | 1 | 4 | 1 | 0 | 0 | 38 | 16 |
| Total | 54,960 | 25,225 | 15,013 | 7,059 | 5,006 | 1,935 | 2,597 | 1,369 |

Table 2 shows that the catches of the potato aphid were more nearly in proportion to the sizes of the openings in the traps than were the catches of the other species. The other species were taken in proportionately larger numbers from the small trap. The question arose as to whether one or more correction factors could be used to convert catches by the small trap to the basis of the large, standard trap.

[1] Accepted for publication May 18, 1955.

Table 2.—Mean ratios of numbers of aphids caught in a large trap to those in a small trap.

| APHID | AUG. 22 TO SEPT. 28 (30 EMPTYINGS) | AUG. 22 TO SEPT. 16 (19 EMPTYINGS) |
|---|---|---|
| Buckthorn | 2.18 | 2.19 |
| Green peach | 2.13 | 2.13 |
| Potato | 2.59 | 2.61 |
| Others | 1.90 | 1.93 |
| All Aphids | 2.18 | 2.19 |

Highly significant correlation coefficients were found between small- and large-trap catches of the three species. These values for the buckthorn, potato, and green peach aphids were 0.8665, 0.9257, and 0.9478, respectively. It was found, however, that the usual approach of regression analysis was inappropriate for determining catch relationships between the small and large traps chiefly because of extreme daily variation in numbers of aphids on the wing in late summer. For the same reason the standard error did not appear to be suitable for testing the significance of the difference between the mean daily catches.

Further study suggested that catch ratios might provide a suitable mode of comparison. All comparisons of this kind were limited to 19 trap emptyings, since that was the number in which all three species were represented in the catches before one or more species became very scarce or was not represented (Table 1). No significant difference, at the 5% level, was found in the mean daily ratios of large- to small-trap catches either among species groupings or in total catch. This indicates that a single ratio might be used to convert small-trap catches to those of the large trap.

A comparison was made of the daily ratios of the total observed catch in the large trap to the expected catch in this trap as calculated by multiplying the catch in the small trap by 2.19 or 2.64. The mean difference between the ratios obtained by the two methods was significant at the 1% level. Since there is no reason to believe that one trap caught more than the other per unit of orifice area, it appears that the small trap retained the catch better than the large one. Thus 2.19 is more appropriate than 2.64 as a factor for converting total catch of the small trap to the large-trap basis. The analyses also indicate that 2.19 is the more appropriate factor for adjusting small-trap catches of individual species to the large-trap basis. Although the catch ratio for the potato aphid most nearly approached the ratio of the orifice areas of the two traps, it did not differ significantly from catch ratios for the other species or groupings.

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## Control of Insects on Hairy Vetch[1]

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Two field experiments were conducted during 1954 in an attempt to develop a program for the control of injurious insects on hairy vetch, while holding mortality of pollinators to a minimum. The pea aphid, *Macrosiphum pisi* (Harr.), and lygus bugs, principally *Lygus lineolaris* (P. de B.), were the only economically important pests that occurred in large numbers during these experiments.

MATERIALS AND METHODS.—In a randomized block, split plot experiment near Terrell, Texas, two levels of demeton and untreated checks were compared in the main plots; sub-plots were established to compare one insecticidal treatment with repeated insectidical treatments. The main plots were $\frac{1}{4}$ acre in size and were replicated five times. On April 20, 1954, the main plots, except the checks, were treated by means of a low gallonage ground sprayer with 2 pounds toxaphene plus $\frac{1}{4}$ pound of demeton per acre or 2 pounds toxaphene plus $\frac{1}{8}$ pound of demeton per acre. Subsequently sub-plots were treated as follows: 10 pounds per acre of 20% toxaphene plus 40% sulfur was applied with a hand duster on May 4; 2 pounds per acre of toxaphene was applied with a hand sprayer on May 14 and 21; 2 pounds of toxaphene plus $\frac{1}{16}$ pound of demeton per acre was applied with a hand sprayer on May 26.

In a randomized block experiment near Greenville, Texas, 2 pounds of toxaphene plus $\frac{1}{8}$ pound of demeton per acre was applied by means of a low gallonage ground sprayer to a $\frac{1}{4}$-acre plot in each of five blocks, with the other plot in each block serving as a check. The insecticide was applied on April 7, 1954, when the first scattering of bloom was found in the field. A $\frac{1}{5}$-inch rain began to fall about 5 hours after the insecticide was applied. An additional treatment of 2 pounds of toxaphene plus $\frac{1}{16}$ pound of demeton in a spray was applied to the treated plots on May 7.

Insect infestations were taken at weekly intervals with a 16-inch insect net. At Terrell, five sweeps per plot were made throughout the season in the sub-plots which received one insecticidal application; only the thrips population was measured in the sub-plots which were treated repeatedly. In the experiment at Greenville, five sweeps per plot were made early in the season, and two sweeps per plot after the aphid infestation became severe. In both experiments the heavier pea aphid infestations were measured by observing the extent to which aphids clustered on small pods and terminals. Control was considered to be adequate when there were few clusters and few aphids per cluster. A satisfactory quantitative criterion for heavier infestations was not developed.

RESULTS AND DISCUSSION.—The numbers of lygus bugs and pea aphids per sweep on selected dates are shown in table 1. At the height of the infestations there were thick clusters of aphids on over 50 per cent of the terminals in the check plots in both experiments. It is believed that in a rapidly increasing population, pea aphids will not do extensive damage to vetch until they begin to cluster thickly on terminals and small pods, providing they are controlled soon after such clustering begins. At 100 to 200 aphids per sweep there are few thick clusters, so control from an insecticidal application is considered to be adequate until this population is reached. On this basis, demeton at $\frac{1}{16}$ pound per acre gave good control of pea aphids for 2 weeks and barely adequate control for 3 weeks; at $\frac{1}{8}$ pound per acre, demeton gave good control for 3 weeks and adequate control for 4 weeks; and at $\frac{1}{4}$ pound per acre, demeton gave good control for 4 weeks and adequate control for 5 weeks. The application of $\frac{1}{16}$ pound of demeton per acre to the sub-plots on May 26 came too late to be of maximum benefit to the vetch; the vetch plants in three of the blocks were sufficiently mature that they were beginning to dry up, and the aphid infestation had already caused some damage in all blocks. The first three days in June were hot, and the aphid infestation disappeared quickly.

The early-spring of 1954 was warm, and the late-spring cool. This probably accounts for the unusually late buildup of pea aphids in the vetch. On the basis of the available information, it seems probable that $\frac{1}{8}$ pound of demeton per acre applied immediately before bloom will give seasonal control of the pea aphid in an average year, and that $\frac{1}{4}$ pound of demeton per acre will give adequate seasonal control in most years.

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Table 1.—Lygus bugs and pea aphids on dates indicated in two experiments to control them on hairy vetch in Texas. 1954.

| Date of Counts | Insects per Sweep: Lygus, Treated May 7 with Toxaphene 2 Lbs. Plus 0.25 Lb. Demeton | Lygus, Treated May 7 with Toxaphene 2 Lbs. Plus 0.125 Lb. Demeton | Lygus, Untreated Check | Pea Aphids, Treated May 7 with Toxaphene 2 Lbs. Plus 0.25 Lb. Demeton | Pea Aphids, Treated May 7 with Toxaphene 2 Lbs. Plus 0.125 Lb. Demeton | Pea Aphids, Untreated Check |
|---|---|---|---|---|---|---|
| | Terrell | | | | | |
| | N / A | N / A | N / A | | | |
| April 20 | 0 / 0.3 | 0.5 / 0.4 | 0.2 / 0 | 0.7 | 2.2 | 1.3 |
| May 14 | 0 / <0.1 | 0.1 / 0.1 | 3.5 / <0.1 | 1.6 | 3.6 | >100[a] |
| May 20 | 0 / 0.1 | 3.2 / 0.2 | 4.5 / 1.0 | 5.5 | 45 | >200[b] |
| May 26 | 0 / 0.1 | 1.1 / 0.3 | 3.3 / 2.1 | 87 | >200[b] | >200[b] |
| | Treated[c] | | Untreated Check | Treated[c] | | Untreated Check |
| | Greenville | | | | | |
| | N / A | | N / A | | | |
| April 7 | 3.0 / 0.1 | | 4.6 / 0.3 | 0.4 | | 0.1 |
| May 4 | 1.8 / 0.7 | | 3.5 / 1.4 | 13 | | 14 |
| May 21 | 0 / 0.1 | | 31.2 / 10.4 | 11 | | >150[a] |
| May 29 | 0 / 0.3 | | 12.8 / 18.8 | >150[a] | | >200[b] |

[a] Thin clusters of aphids on terminals and small pods.
[b] Thick clusters of aphids on about 50 per cent of the terminals.
[c] Sprayed on April 7 with 2 lbs. of toxaphene and ¼ lb. of demeton per acre; on May 7 with 2 lbs. of toxaphene and 1/16 lb. of demeton per acre.

The experiments in 1954 and records on 10 unreplicated demonstration plots in 1953 indicate that lygus bugs on vetch can be controlled adequately for the season with one application of insecticide, if the insecticide is applied when there are only nymphs in the field. Since vetch is an early-season crop, it may be that, except in unusual years, a pre-bloom insecticidal application can control lygus bugs when there are few adults in the field. The unreplicated tests gave a strong indication that demeton alone will partially control nymphal lygus.

Slight thrips damage to the vetch could be observed, but at no time during the season did the thrips population become large enough to cause extensive damage. Walking through the vetch to make the four applications of insecticides with a hand duster or sprayer damaged the vetch badly, however, and seed yields in the sub-plots which received these applications reflected this damage.

Two randomly selected square yards of vetch from each plot were harvested by hand on June 16. In the experiment at Terrell, the subplots which were treated once with 2 pounds of toxaphene plus ¼ pound of demeton per acre yielded a mean of 539 pounds of No. 1 vetch seed per acre; the remaining sub-plots yielded means of 349 to 394 pounds per acre. Neither the main treatments nor the sub-plot treatments resulted in a significant increase in seed yield. In the experiment at Greenville, the treated plots yielded a mean of 475 pounds, the untreated plots, 334 pounds of No. 1 vetch seed per acre. The F value for treatments was 6.68; a value of 7.71 would be required for significance.

These experiments were conducted in the hope that a program could be developed to control the injurious insects on vetch without killing the pollinating insects. It was found that demeton is highly toxic to honey bees as a contact poison when sprayed directly upon them, but foraging bees captured in plots which had been treated with demeton lived as long in the laboratory as bees captured in other fields. There was no evidence that the pre-bloom applications hurt the honey bees in any way.

SUMMARY AND CONCLUSIONS.—Two experiments were conducted to study the control of insect pests of hairy vetch with toxaphene and demeton.

A single treatment of toxaphene and demeton applied to vetch before it begins to bloom heavily shows great promise as a seasonal control for lygus bugs and pea aphids with a minimum of damage to pollinating insects.

## Colonization of Imported Pink Bollworm Parasites[1]

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Importation and colonization of parasites of the pink bollworm, *Pectinophora gossypiella* (Saund.), were begun at Presidio, Tex., in 1932 and discontinued in 1944. In 1952 the work was resumed at Brownsville, Tex. A rapid spread of the pink bollworm beginning in 1950 and a build-up in southern Texas were believed to afford more favorable conditions for parasites to maintain themselves than at the time of the previous releases.

INVESTIGATIONS AT PRESIDIO.—The work at Presidio from 1932 to 1936 was reported by Noble & Hunt (1937). At the end of that period releases had been made in Texas, Mexico, and Puerto Rico, and the field sampling had failed to show that any of the species had become established.

Beginning in 1937 several new species were received for propagation, and releases were continued of those already on hand except *Bracon brevicornis* Wesm., which was believed to have had ample opportunity to become established. Table 1 lists the species and their place of origin, and shows the localities and number of each species released in areas infested with the pink bollworm. All these species were recovered in field collections made in the current summers of the releases and, with the exception of *Bracon kirkpatricki*, all were found to live overwinter in hibernation cages. However, extensive collections in years following the

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[2] In cooperation with the Texas Agricultural Experiment Station.

Table 1.—Numbers of pink bollworm parasites liberated, 1937–44.

| PARASITE | PLACE OF ORIGIN | TEXAS | MEXICO | PUERTO RICO | TOTAL |
|---|---|---|---|---|---|
| *Bracon kirkpatricki* Wilk. | East Central Africa | 108,235 | — | — | 108,235 |
| *Bracon mellitor* Say | Hawaii | 30,543 | — | — | 30,543 |
| *Bracon nigrorufum* Cush. | Japan | 57,955 | 61,000 | — | 118,955 |
| *Chelonus blackburni* Cam. | Hawaii | 1,109,500 | 100,000 | — | 1,209,500 |
| *Chelonus pectinophorae* Cush. | Japan | 447,000 | — | — | 447,000 |
| *Exeristes roborator* Fab. | Egypt | — | — | 6,392 | 6,392 |
| Total | | 1,753,233 | 161,000 | 6,392 | 1,920,625 |

liberations failed to show that any became established. These collections also gave further evidence that *M. brevicornis* and *Exeristes roborator* had not established themselves from previous releases in Texas and Mexico. The stocks of two other species, *Bracon vulgaris* Ash., and *Calliephialties dimorphus* Cush., received from Brazil, died in the laboratory before any releases were made.

INVESTIGATIONS AT BROWNSVILLE.—Five species shipped from India through the Moorestown, N. J., laboratory were propagated for release in 1953 and 1954. In addition to the rearing at Brownsville, some of the parasites were increased at Moorestown and forwarded via air mail for liberation. Releases were made in the Brownsville, Port Lavaca, and Eagle Pass areas of Texas and in Tamaulipas, Mexico. The Texas areas included 15 counties. Table 2 lists the number of each species released in Texas and Mexico. *Bracon greeni* Ash. was also received from India, but the stock died in the laboratory before any releases were made.

In 1953 and 1954 some rearing was done from field-collected bolls to see if any parasites might be recovered. Several generations could have occurred between the liberations and the collection of bolls. From the 1953 collections 100 bolls were put in each of 10 screen cages approximately 18 by 6½ by 12 inches, and the battery of cages was covered with a double thickness of black cloth and a removable plywood front. In each cage was a hole in which was inserted a vial about 1 inch in diameter extending through the black cloth to attract and catch the emerging insects. In 1954 it was decided to use a 1000-boll sample. The bolls were enclosed in a pyramidal cage which was lined with cloth to prevent the smaller insects from escaping. A glass jar with an inverted wire cone having a hole in the center was placed in the apex of the cage to trap the insects.

Although 9,891 pink bollworm moths emerged from the bolls collected at 14 liberation points, none of the imported parasites were recovered. No doubt the use of insecticides for cotton-insect control hindered propagation of the parasites. It is believed that the sampling thus far has not been adequate for conclusions as to whether or not any of the species released from Brownsville have maintained themselves in low populations. In future work there is need for increased effort to determine if any of the parasites have become established, including attempts to recover them from either cotton or other host plants of the pink bollworm as well as from other insect hosts.

Table 2.—Numbers of pink bollworm parasites liberated, 1953–54.

| PARASITE | TEXAS | MEXICO | TOTAL |
|---|---|---|---|
| *Apanteles angaleti* Meus. | 69,536 | 2,194 | 71,730 |
| *Bracon brevicornis* Wesm. | 303,092 | 11,000 | 314,092 |
| *Bracon gelechiae* Ash. | 299,426 | 11,000 | 310,426 |
| *Chelonus* sp. No. 1 | 18,493 | — | 18,493 |
| *Chelonus* sp. No. 2 | 8,256 | 289 | 8,545 |
| Total | 698,803 | 24,483 | 723,286 |

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## Oxygen Consumption of Resistant and Susceptible House Flies[1]

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Workers in a number of laboratories have tried to find physiological differences between strains of house flies resistant versus susceptible to DDT and other insecticides. The present note can be made brief because it reports only the absence of any qualitative difference in respiratory enzyme composition as judged by temperature kinetic determinations.

The strains of flies used were obtained from Dr. George C. Decker in 1953. They were a susceptible strain (CSMA), a strain resistant to DDT (DMC), and a strain resistant to DDT, BHC, lindane, dieldrin, aldrin and several other insecticides (Multi-X). These were reared under standard conditions, and the oxygen consumption measured as a function of temperature mostly in the period of 5 to 10 days after adult emergence. Some flies were handled individually in Warburg flasks, but most of the determinations were made with groups of 3 to 25 flies in respirometers patterned after those of Flemister and Flemister (1951) but with the two chambers of the same size (about 50 cc.) and with a 1 ml. tuberculin syringe. They were equilibrated in a water bath held to $\pm 0.1°$ C.

Several hundred determinations were made of $Q_{O_2}$ (ml. $O_2$/gm. wet wgt./hr.). The number of $Q_{O_2}$ determinations × the number of flies employed was over 6,500. Since, in general, similar numbers were used for each strain at each temperature, each point of the graph (Fig. 1) represents the average from about 130 fly determinations except for the overall averages (solid circles) where each point represents about 400 fly determinations.

Figure 1 shows the data presented as an Arrhenius type plot for the range 10–45° C. Maximum oxygen consumption would be at or above 45° C. since the curve is still essentially straight up to this temperature. From the line drawn through the average values (solid circles) one can calculate that the $\mu$ value of the Arrhenius equation is approximately 11,000 cal./mol. This is a lower value than many insects show for oxygen consumption but is similar to the value from certain species (Edwards 1953).

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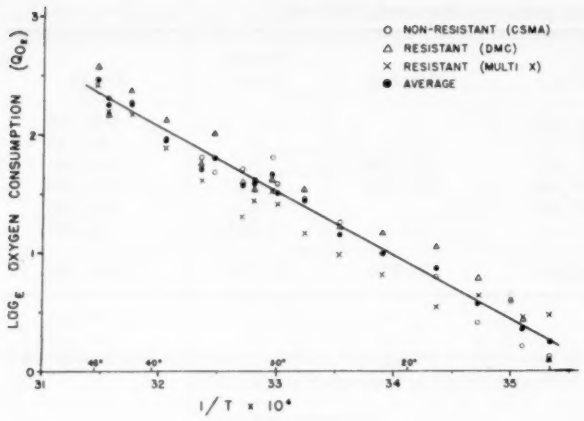


FIG. 1

It is the value commonly associated with cytochrome-mediated respiration (Sizer 1943). It is considerably lower than the value (*ca*, 20,000) shown by points on Edwards' curves (1946, 1953) for the house fly.

Plots of oxygen consumption always show more scatter of points than one would like (see figures in Edwards 1953). Within the limits imposed by this scatter there is clearly no significant difference shown in the slopes of the lines for these three strains. Therefore there is no indication of any qualitative difference in that part of the respiratory enzyme complement which controls the temperature effect. Over much of the curve it appears that the absolute values for the Multi-X strain are lower; if this were true over the entire curve it would imply a quantitative difference between strains, but the significance of this apparent difference is made questionable by higher values at each end of the curve.

We have to conclude that our measurements fail to show any significant difference in oxygen consumption for resting individuals of these three strains of house flies.

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## Notes on the Biology and Control of *Pseudocneorhinus bifasciatus*[1]

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Although Britton (1924) was the first to report the occurrence of the Japanese weevil *Pseudocneorhinus bifasciatus* Roelofs in the United States from specimens collected in 1920 in Connecticut, Buchanan (1946) later referred to specimens that had been collected in 1914 in a nursery near Philadelphia. Both these authors referred to collections from several towns in Connecticut and Long Island, also in Moorestown, N. J., and Washington, D. C. Soraci (1947) found this insect widespread in northern New Jersey. Kuwayama (1932) reported it attacking strawberries in Japan.

Recorded hosts included azalea, Japanese barberry, lima beans, *Bidens* sp., forsythia, geranium, hemlock, mountain laurel, lilac, lily-of-the-valley, mimosa, California privet, rhododendron, strawberry, veronica, and weigelia (Soraci 1947; Britton 1924, 1932, 1933, 1934; Kuwayama 1932; Buchanan 1946; and Allen 1949).

The observations reported herein were made in 1953 and 1954 on infestations in College Park and Beltsville, Md., and in Washington, D. C., where plants in several adjacent properties were infested. Azalea, barberry, chrysanthemum, clematis, elm, fern, forsythia, lilac, California privet, Regels Border privet, rhododendron, rose, rose of Sharon, and vanhoutte spirea were moderately to severely injured.

Although Britton and Soraci referred to this weevil as "*Pseudocneorrhinus setosus* Roelofs," Buchanan stated that all American specimens trace to *Pseudocneorhinus bifasciatus* Roelofs and that the species present in America should be called by this name. The presence of denticles on the hind tibiae of *bifasciatus* differentiates it from other members of the genus.

This Japanese weevil has fused wing covers and cannot fly. All specimens that Buchanan dissected were females, and he concluded that the species is probably parthenogenetic. Previous workers reported no observations on immature stages, but the writer frequently observed small, cream-colored, elongate eggs in partially eaten, curled, and dried leaves.

Although the weevils feed in the daytime and cling to the twigs of a plant, they are easily overlooked because of their subdued brown coloration and markings. On dense bushes such as spirea they tend to feed on the inner foliage, so that the plant appears to be in poor growth. The adults eat notches in the leaf edges until only the petiole is left. Adults were observed first on June 7, and some lived until November 10 on caged azalea.

They occur in great numbers on a plant. R. A. St. George and the writer collected 265 adults from a single large spirea bush that was defoliated except for the tip growths.

Britton (1933) reported that nicotine sulfate sprays had no effect on the adults and that lead arsenate sprays repelled the weevils but did not kill them. Allen (1949) found in preliminary

[1] Accepted for publication July 22, 1955.

**Table 1.—Effectiveness of insecticide dusts against *Pseudocneorhinus bifasciatus*.**

| INSECTICIDE (PER CENT) | | NUMBER OF WEEVILS IN TESTS | PER CENT OF WEEVILS KILLED |
|---|---|---|---|
| Pyrophyllite check | | 40 | 0 |
| Aldrin | 2.5 | 24 | 100 |
| | 1 | 18 | 83.3 |
| Chlordane | 5 | 25 | 100 |
| | 2.5 | 18 | 100 |
| | 1 | 18 | 83.3 |
| DDT | 10 | 25 | 0 |
| Dieldrin | 2.5 | 20 | 100 |
| | 1 | 17 | 100 |
| Endrin | 2.5 | 20 | 0 |
| | 1 | 20 | 0 |
| Heptachlor | 5 | 20 | 100 |
| | 2.5 | 18 | 100 |
| | 1 | 17 | 47 |
| Isodrin | 2.5 | 20 | 100 |
| | 1 | 18 | 33.3 |
| Lindane | 2.5 | 20 | 0 |
| | 1 | 20 | 0 |
| Malathion | 4 | 20 | 100 |
| | 2.5 | 18 | 100 |
| | 1 | 20 | 0 |
| Methoxychlor | 10 | 20 | 0 |
| Parathion | 2.5 | 28 | 100 |
| | 1 | 25 | 0 |
| Toxaphene | 10 | 20 | 0 |

tests at Moorestown, N. J., that chlordane was more effective than BHC, DDT, or lead arsenate.

In tests at Beltsville for the control of this weevil, 12 insecticides in dusts with pyrophyllite as diluent were compared on caged azaleas and 2 on infested garden plantings. DDT, endrin, lindane, methoxychlor, and toxaphene were nontoxic at the concentrations tested. The minimum concentrations that killed all weevils appeared to be 2.5 per cent of aldrin, chlordane, heptachlor, isodrin, malathion, and parathion, and 1 per cent of dieldrin. High but incomplete kills were also obtained with 1 per cent of aldrin and chlordane.

Although these dusts had killed all the weevils at the end of 8 to 12 days, they varied considerably in their speed in causing paralysis and death. Aldrin, dieldrin, and heptachlor usually caused them to become paralyzed and drop to the ground within 6 hours, and death followed with almost no feeding on the foliage. Chlordane, isodrin, malathion, and parathion caused slower paralysis, over a period of 4 to 6 days, and there was slight to moderate feeding injury before the weevils succumbed.

Dusts containing 5 per cent of heptachlor or 2.5 per cent of aldrin killed adult weevils infesting plants on two properties. Because weevils appeared in 1954 on one property treated in August 1953, it was evident that treatment earlier in the season is required to prevent oviposition.

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## Longevity and Emergence of the Sheep Ked[1]


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Two important questions pertaining to control of the sheep ked, *Melophagus ovinus* (L.), concern the length of the pupal stage and the time a ked can remain alive off the host. It was thought most plausible that temperature might influence both these factors. The tests described below indicate this theory to be true.

Sheep ked puparia were collected and stored at several constant temperatures. The relative humidity ranged from 60 to 80 per cent. Information was also obtained on the per cent emergence from puparia at these temperatures. A total of 40 puparia were used at each temperature in two replicate tests.

At 70°, 80°, and 90° F. the average life span was 63, 80, and 38 hours and emergence was 52, 75, and 67 per cent over periods of 32, 22, and 17 days, respectively. At room temperature (60°–75° F.) the longevity of unfed adults was as much as 200 hours, and adults have emerged from pupae even after 61 days.

In another test 20 puparia were kept at 40° F. for 20 days, but no emergence took place. Therefore they were transferred to a 90° chamber, but still no emergence could be obtained. Exposing puparia to temperatures of 20°–30° F. for 24 to 48 hours did not materially reduce the emergence below that of puparia at room temperature, however.

In one group of 63 puparia maintained at room temperature only 27 per cent emerged over a 37-day period. At biweekly intervals during the following 50 days the remaining puparia were examined and all pupae were dead.

These tests indicate that the optimum temperature for emergence of sheep ked pupae is between 80° and 90° F., and that the longest life span of unfed keds is obtained near 80°. The pupal stage is shortened by warm temperatures, but the adults survive longer at a moderate temperature. Prolonged exposure to low temperatures kills puparia, but short exposures to subfreezing temperatures are not noticeably detrimental.


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## Penetration of the Foliage Canopy of Corn and Potatoes by Aerial Spray


CALVIN E. DEONIER, *Entomology Research Branch, Agr. Res. Serv., U.S.D.A.*[1]


During the summer of 1954 investigations as to how much of a spray applied by an airplane penetrates downward through the foliage canopy were conducted on sweet corn near Prosser, Wash., and on potatoes near McDoel, Calif.

Sprays of water containing a tracer dye (DuPont Pontacyl Carmine 2 B, or equivalent water-soluble dye) were applied by a government-owned N3N airplane with 59 open-cone nozzles (orifice diameter $\frac{1}{8}$ inch) placed 4 inches apart 9 feet 8 inches each side of center. Two 30-foot swaths were flown at elevations of 2 feet above vegetation on corn and 4 to 5 feet on potatoes.

Stainless steel plates 3 by 6 inches were placed in each row from center to center of the swaths and at right angles to the line of flight. In the corn the plates were placed at the tassel, silk, and ground level, and in the potato fields at the tops and base of the vines on the hills and in the furrows between the rows. The deposit was quantitatively determined by usual colorimetric procedures (Chamberlin *et al.* 1955).

The spray must penetrate to the insect to be effective. It must reach the silk level in corn to have an effect on corn earworms, *Heliothis armigera* (Hbn.). Similarly, it must penetrate to the hill and furrow level in potatoes to contact the green peach aphid, *Myzus persicae* (Sulz.), whose favored habitat is the under surface of the basal leaves.

On corn it was found that 42 per cent as much spray penetrated to the silk and 11 per cent as much to the ground as to the tassel level. With potatoes 37 per cent as much spray penetrated to the hill level and 31 per cent as much to the furrow level as to the vine top.

The effective insecticide coverage, for control of aphids on potatoes in particular, is much less than is indicated by these percentages, since most of the spray reaching the lower leaves is deposited on their upper surfaces and hence does not actually contact most of the aphids, which are on the undersides of the leaves.

### REFERENCE CITED


**Chamberlin, Joseph C.,** C. W. Getzendaner, H. H. Hessig, and V. D. Young. 1955. Studies of Airplane Spray-Deposit Patterns at Low Flight Levels. U. S. Dept. Agr. Tech. Bull. **1110** (In Press).



[1] In cooperation with the Agricultural Engineering Branch, Agricultural Research Service, U.S.D.A., and with the Oregon and Washington Agricultural Experiment Stations. Accepted for publication April 20, 1955.

# EDITORIALS

## Financing the Journal

The problem of financing the publication of scientific journals is as old as the journals themselves. No permanent solution has been found, and many of the temporary expedients have serious disadvantages. The JOURNAL OF ECONOMIC ENTOMOLOGY is not in serious financial difficulties, but it is obvious that more revenue must be found in the near future.

There are three ways to meet this problem: (1) by reducing the cost, (2) by increasing the subscription price, and (3) by obtaining some sort of subsidy.

The simplest method of reducing the cost would be to return to volunteers for editor and for business manager. On the balance sheet the relatively small honoraria paid volunteers look attractive in terms of money saved for the Society. The previous editors have done a remarkable job in publishing the JOURNAL. But each time an editor has resigned it has been difficult to find another to accept the post. At least one institution has advised its entomologists to avoid this post because of the time required. The task is now so large that one man cannot handle it in his spare time, and no one institution should be expected to subsidize the post. A return to a volunteer staff does not offer an entirely satisfactory solution.

A large group of loyal members with sufficient professional pride can finance the JOURNAL. The cost would be considerably more than the present subscription price, but would be no greater percentage of 1955 salaries for entomologists than the cost of the same JOURNAL 30 years ago.

Subsidies have always created problems. Many societies avoid them at all costs. The chief fear is that the contributor of the subsidy will control the editorial policies of the publication. Most entomologists have forgotten that the first 19 reports of the American Association of Economic Entomologists were published by the U. S. Department of Agriculture. Most members never even knew that the JOURNAL OF ECONOMIC ENTOMOLOGY was started as a private venture by a few members, and did not appear as a Society publication until Volume 11 in 1918. The first 19 years represented a complete subsidy, and the next 10, if not a subsidy, at least no obligation of the membership.

At the present time the best source of a subsidy seems to be the institutions from which papers are submitted for publication. In fact, it may be that publication in journals instead of bulletins has contributed to the present difficulties. All research organizations consider that publication of results is an integral part of research. Most grants-in-aid include the cost of publication as a suitable item of expense of research.

The journal *Phytopathology* has adopted a system under which institutions must buy 100 reprints at a cost large enough to cover part of the cost of printing the journal. Additional reprints may be purchased at usual reprint prices. This system has worked well in practice and has improved income substantially. It is worth consideration for the JOURNAL OF ECONOMIC ENTOMOLOGY. It offers a logical system under which the institution takes part of the cost of publication of its research in journals, rather than requiring its entomologists to pay the entire bill.

NEELY TURNER,
*Connecticut Agricultural Experiment Station, New Haven*

## Try Giving Yourself Away

One of the most impressive human interest stories appeared in the August, 1945 issue (page 27) of *Readers' Digest*. It was entitled "Try Giving Yourself Away."

Entomologists, like other professional men, have an obligation to provide incentives to the less experienced workers. I recall the encouraging letter I received from L. O. Howard some 45 years ago, commending me on a publication written as a bachelors' thesis and published as a technical bulletin of the U. S. Bureau of Entomology. I have since learned that it was Doctor Howard's rule to write such congratulatory letters to the younger entomologists whenever he read a contribution useful to the science of Entomology. In my estimation, such complimentary letters have undoubtedly been the responsible incentive to many embryo entomologists for greater achievements and contributions to the Science of Entomology.

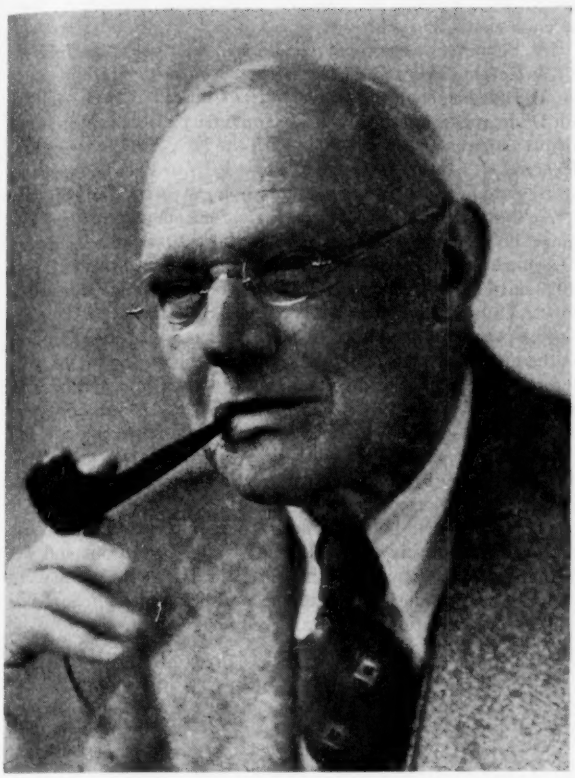
Perhaps most of us do not realize the value of "giving yourself away." I recall, for example, upon the death of my wife, I wrote my physician, expressing appreciation of his aid, which had extended over a period of three "day and night" weeks. His reply was almost pathetic for he was deeply appreciative, offering the additional thought that it was rare that he, as a physician, ever received a word of commendation, especially when he lost his patient. Such commendation, he said, gave him the courage and ability to go on.

Let us all be more appreciative of the achievements of our fellow workers—commend them when commendation is deserved, and give help when needed.

J. J. DAVIS,
*Purdue University*
*Lafayette, Indiana*

# OBITUARIES

## Lawrence Peck Rockwood
## 1886-1955



**Lawrence Peck Rockwood**

With the death of Lawrence Peck Rockwood in Forest Grove, Oregon, on April 14, 1955, we lost another of the few remaining entomologists of the "old school." Mr. Rockwood was born on October 13, 1886 in Waterbury, Connecticut, son of Charles Henry and Alba Peck Rockwood. He was great grandson of William Dandridge Peck, one of the earliest American economic entomologists. He was graduated from the Massachusetts Agricultural College in 1912 with a B.S. degree and was elected to the honorary national scholastic fraternity, Phi Kappa Phi, the same year. In 1927 he was elected to the Oregon Chapter of Gamma Sigma Delta, honorary national agricultural fraternity. Mr. Rockwood was a member of the Ancient Free and Accepted Masons; Fellow, A.A.A.S.; member, Amer. Assoc. Econ. Ent., Ent. Soc. of Am. and Ent. Soc. of Washington.

In 1916, Mr. Rockwood was married in Forest Grove, Oregon to Ethel Maude English, who died in 1946. He is survived by three children, Mary Rockwood Cowan, Maj. William Peck Rockwood, Harry English Rockwood, and one brother, Nathan C. Rockwood, to all of whom our heartfelt sympathies are extended.

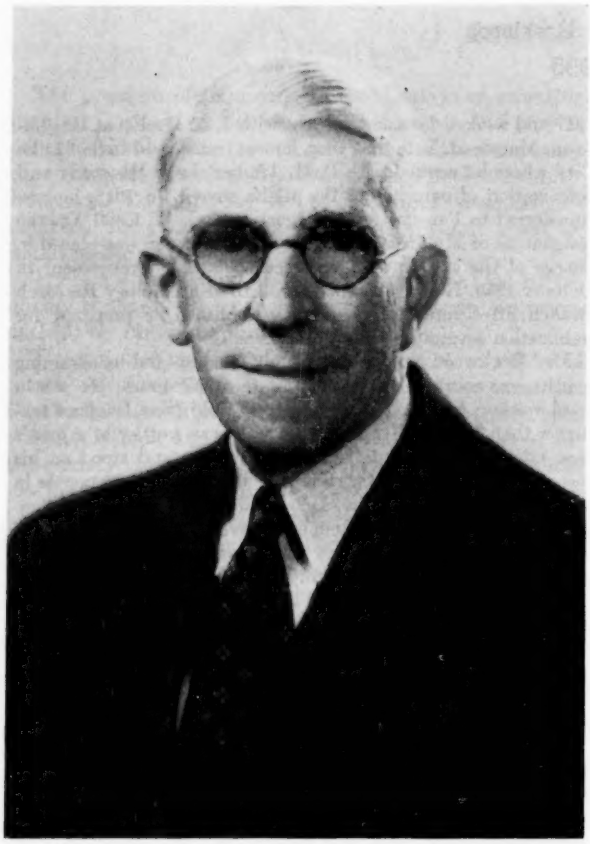
Mr. Rockwood began service in the Division of Cereal and Forage Insect Investigations of the Bureau of Entomology in 1912 and worked for a few months with J. A. Hyslop at Hagerstown, Maryland. Late that year, he was transferred to Salt Lake City where he worked with P. H. Timberlake in the study and colonization of parasites of the alfalfa weevil. In 1915, he was transferred to Forest Grove, Oregon, with C. W. Creel. On the resignation of Mr. Creel in July, 1919, Rockwood was placed in charge of the station and remained so until his retirement in October 1948. He was collaborator of the Entomology Research Branch after retirement and has published or prepared for publication several important papers since.

Mr. Rockwood was an extremely modest and unassuming gentleman, courteous and considerate at all times. He was a hard worker, believing according to the old New England tradition that "the job," whatever it was, was worthy of a man's best efforts. He was intellectual, self reliant and stood on his own feet and preferred that his associates, as well as people in general, should do likewise. He was definitely not of the "go-getter" type and was not inclined to give unneeded or unsought advice but when help of any kind was requested of him, he gave it freely and wholeheartedly. He was an honorable man in every sense of the word,—loyal to his friends, generous and fair to all. He had no desire to "break into print" and since thoroughness was one of his more noticeable characteristics, his list of publications is not as long as it could have been. Mr. Rockwood had a remarkable faculty of remembering accurately and in considerable detail anything read or observed. Since he was an inveterate reader, this faculty enabled him to locate and use published work of other entomologists with less effort than is required by many other investigators. He always regarded fellow entomologists as men of intelligence and integrity and in his publications their work was gauged fully and impartially on this basis. Remaining clear-headed to the last, he was able to analyze and correlate results of his work and that of others with unusual success. He recognized the importance of detail but this did not cause him to lose sight of major purposes of his investigations, in which his considerable knowledge of agriculture in general, botany, plant pathology, mycology, and climatology served him well. He was a good taxonomist and made thorough studies of the taxonomy of grasshoppers, adults and larvae of Phalaenidae and other groups of the Pacific Northwest. He also studied over a long period the taxonomy and development of entomogenous fungi.

Whatever may be one's opinion of Rockwood's research methods, he apparently was one of our most highly successful researchers for in my opinion and that of many others his knowledge of insects attacking cereal and forage crops in the Pacific Northwest was the most extensive, detailed, and accurate possessed by any one man. He was the type of investigator who "kept his feet on the ground" and was not carried away by entomological "fads." He knew when the newer approaches were sound and where they could be used to advantage. It is a great loss to all of us that, regardless of his publications and numerous notes which remain, so much information must go with the man, but speaking more selfishly, the greatest loss is that of so fine a friend.

T. R. Chamberlin

## William Jay Schoene
## 1879-1955



William Jay Schoene

Dr. William Jay Schoene, who retired several years ago from service with the Virginia Agricultural Experiment Station, passed away on March 30, 1955, in Venice, Florida. His home was in Blacksburg, Virginia, but he and his wife were spending the winter in Florida. He is survived by his wife, three daughters, a son, a sister, and a brother.

Dr. Schoene was born at Henderson, Kentucky, on July 27, 1879. He obtained a B.S. degree from Kentucky State in 1905, an M.S. degree from the University of Chicago in 1911, and the Ph.D. degree from the Ohio State University in 1928. From 1905 to 1913 he was an entomologist with the New York Agricultural Experiment Station at Geneva. From 1913 to 1926 he served as state entomologist, principal entomologist with the Virginia Crop Pest Commission, and teacher of entomology at the Virginia Polytechnic Institute. For a short time he was acting Director of the Virginia Agricultural Experiment Station. From 1926 until his retirement he was leader of entomological research in the Virginia Agricultural Experiment Station.

The primary interest of Dr. Schoene was fruit insects, and he is the author of many publications dealing with the life history, habits, and control of insects affecting apples and peaches. He was a member of the Entomological Society of America, the American Association of Economic Entomologists, and the Society of the Sigma Xi. In community affairs he was an elder in the Blacksburg Presbyterian Church, a Mason and, at one time, a member of the town council.

Dr. Schoene will be remembered by his close associates as one whose word was his bond. He had strong convictions and was rather individualistic in the things he did. His actions were motivated by a genuine interest in the well-being of his fellow man and in the institution which he served for so many years.

JAMES MCD. GRAYSON
L. R. CAGLE

## Samuel Bradford Doten
## 1875-1955

Samuel B. Doten, one of the old-time entomologists of the West, died suddenly in Reno, Nevada on May 9, in his 80th year.

Professor Doten was chief entomologist of the Nevada Agricultural Experiment Station at Reno from 1900 to 1946, and from 1913 to 1946 he was also Director of the Station. He was renowned as a scholar, he taught entomology for some years and did extensive research work in economic entomology, specializing in insect damage to trees. One of his better known researches was a very thorough study of the European elm scale, the results of which were published in a Nevada Station Bulletin in 1908. He also published on grasshoppers, horse flies, eelworms and parasitic insects.

Born in Gold Hill, Nevada, Dec. 14, 1875, Sam Doten was the son of the editor of the *Gold Hill News*. His father was a friend of Mark Twain, then editing the *Territorial Enterprise* in nearby Virginia City. Gold Hill is now a nearly abandoned mining town. Sam Doten graduated from the University of Nevada in 1898 and later got a master's degree at the same university. In 1915 he married, and his wife died in 1943. His entire life was spent in and about Reno, and he became well-known there in his later years for his ability to tell stories of the early mining days. He was the last one to carry the name Doten in Nevada.

E. J. NEWCOMER